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ON A SELF-RECORDING METHOD APPLIED TO THE MOVEMENTS OF STOMATA.

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(WITH FIFTEEN FIGURES)

In my paper on stomata[1] it was incidentally shown that the temperature of a leaf varies, other things being equal, with the condition of the stomata. Thus if there are two leaves, in one of which (O) the stomata are open, while in the other (C) they are closed, it is found that O is cooler than C. It is evident that this must be so because the evaporation from O is greater than that from C; in fact, one corresponds to the wet bulb, and the other to the dry bulb of a psychrometer. In the experiments above referred to the leaves employed were those of Tropaeolum, C being a leaf in which the stomata were closed by separating it from the plant, and thus allowing it to wither; while O was a leaf still attached to the plant, with normally open stomata. As the stomata of O closed in the evening, its temperature approached more and more to that of C, and to that of the dry bulb thermometer, while the temperature of an aquatic leaf (of a species in which the stomata are open at night) remained cooler than the dry bulb thermometer.

These experiments suggested that the changes in the temperature of a leaf might be used, with certain precautions, as an index of the condition of the stomata. It was hoped that by the use of this method it would be possible to check and control

[1] DARWIN, FRANCIS, Observations on stomata. Phil. Trans. Roy. Soc. London B. 190: 582. 1898.

observations made by the horn hygroscope, as given in the above-quoted paper.

METHOD.

The apparatus employed was one of Callendar's recorders, a platinum thermometer,[2] or resistance thermometer, in which the difference between the temperatures of two fine platinum wires is recorded on a revolving drum.[3] In the experiments illustrated by *figs. 1, 2, 3, 5, 6, 12, 13, 14, 15*, the resistances were so arranged that a vertical fall of 24^{mm} in the tracing made represents a difference of 1° C. But as some of the figures have been reduced in scale it is simpler to state that the distance between the horizontal lines represents one-sixth of a degree C. In *figs. 4, 7, 8, 9, 10, 11*, the value of 1° C. is uncertain, owing to an omission in my notes. In these figures the distance between the horizontals represents either 0.1° or 0.2° C.

The fine platinum wires, the difference of whose temperature is recorded, are disposed in fine zigzags on plates of talc 10×3^{mm}, which will be referred to as "bulbs." The leaf is inverted, so that its stomatal surface is free, and its astomatal surface is in contact with the wire. It is generally necessary to hold the petiole in a clamp, and to press the leaf against the bulb by a pair of springs, or by a thread having weights at each end. An unavoidable drawback of the apparatus is that, owing to the current run-

[2] The instrument was made by the Scientific Instrument Company at Cambridge. I am much indebted to my brother, Horace Darwin, for help in management of the apparatus.

[3] A resistance thermometer, or, as it is often called, a platinum thermometer, consists of a fine platinum wire, which is exposed to the temperature it is desired to measure. As its temperature alters, its electric resistance also alters, and by measuring this resistance the temperature is found. These thermometers are usually made of platinum, but this is not necessarily the case; a fine wire of copper or of other metal can be used in many cases with equally good results. The resistance is usually measured by a Wheatstone bridge; the Callendar recorder is an automatic Wheatstone bridge, which is continually measuring the resistance, and at the same time moves a pen so that its distance from a fixed point is proportional to the temperature. This pen marks a line on a drum driven by clock-work, and thus a curve is drawn giving a continuous record of the temperature of the thermometer. By the use of two resistance thermometers a curve can be made representing the difference of their temperatures, and this is the arrangement which I have employed. See Callendar Electric Recorders, a pamphlet published (1901) by the Cambridge University Press.

ning through the wires, the bulbs are warmer, by roughly 2°, than the surrounding air. Thus the leaf under experiment is not in strictly natural conditions, being constantly warmed; in spite of the artificially increased transpiration[4] due to this condition,

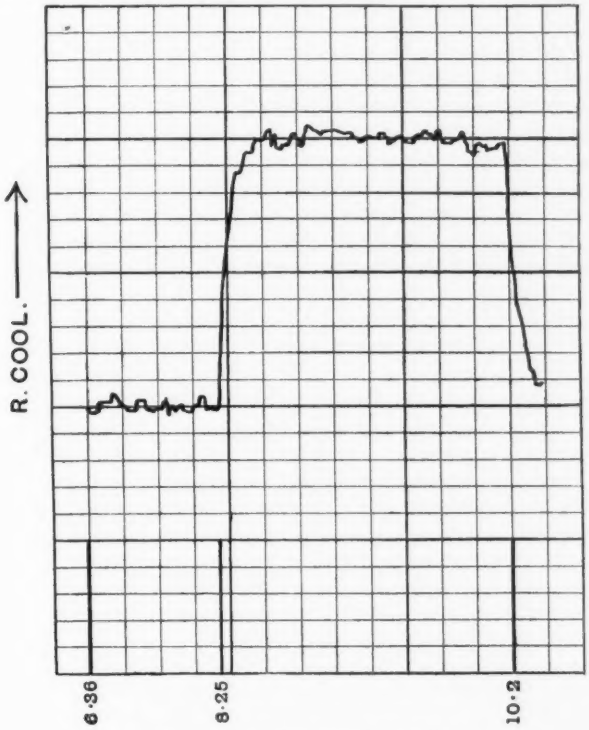

FIG. 1.—See Experiment 83 B, p. 84.

the leaf behaves normally in showing a marked rise in temperature as the stomata shut. Nor does the warming of the leaf,

[4] By the use of the horn hygroscope it is possible to show that the part of a leaf in contact with the recorder bulbs transpires more than the unheated parts of the same leaf. The following are readings taken on a tulip leaf, February 22, 1901, B being the transpiration of the part of the leaf in contact with the bulbs, N of the normal parts of the leaf.

P. M.	N	B
4:53	30	40
10:43	23	30

generally speaking, prevent the stomata showing normal behavior, *e. g.*, in closing at night, or by artificial darkness during the day, or again when the petiole is divided and the leaf begins to wither.

The purely physical results of the warmth of the bulbs have also to be considered. Supposing the apparatus is in equilibrium, and the pen therefore is running along the zero line, indicating equality of temperature in the bulbs; if a bad conductor, such as a flock of cotton wool be placed on one bulb, the pen will instantly be deflected, as shown at 8:25 P. M., *fig. 1*.

EXPERIMENT 83 B, *fig. 1*. *July 2, 1900*. COTTON WOOL.

P. M.	
6:36–8:20	Nothing on either bulb.
	The battery turned off, and a thick pad of cotton wool placed on bulb B; this prevents loss of heat from B, and therefore gives an R-cool[5] movement when the battery was turned on.
8:25	Battery on: result, an R-cool rise of about 1.7° C.
10:2	Wool removed: result, an R-warm fall.

In the same way, if a good conductor, *e. g.*, a thin metal plate or a withered leaf, is placed on bulb R, the result shown at 5:56 in *fig. 2* will be seen; the effect of its removal is seen at 8:28.

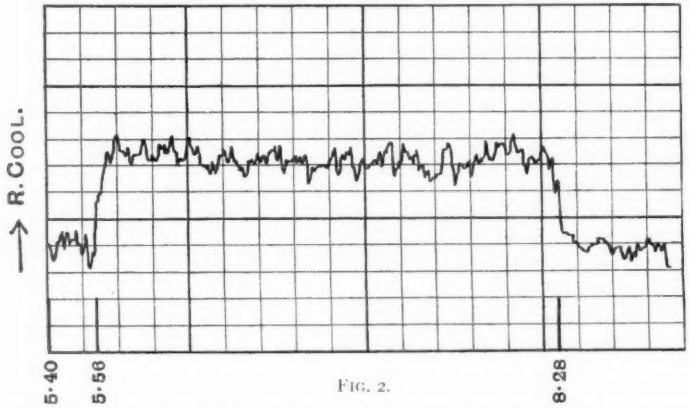

FIG. 2.

It is clear that these facts must be taken into account in experiments on leaves. This difference in temperature would not in

[5] The two bulbs of the thermometer are distinguished as bulb B and bulb R. When the pen is deflected from the zero line it indicates a difference of temperature between B and R which may be called a "B-warm" or "R-cool" effect; while a ontrary effect would be described as either "B-cool" or the equivalent "R-warm."

any way indicate the cooling effect of transpiration, because the leaf used is one cut from the parent plant, in which the stomata had closed; the leaf simply acts as a good conductor.

In most experiments a leaf with stomata shut was placed on the control bulb, the experimental leaf being on the other. This has not merely the advantages pointed out, but it has the more important effect of protecting the control bulb from draughts of air, and therefore from changes in temperature. The effect is evident when both bulbs are covered with cotton wool. The line drawn is then quite free from the zigzags so evident in the figures published. The following experiment shows that it is important to choose carefully the body placed on the control bulb.

EXPERIMENT 46, *fig. 3, Dec. 18, 1899.* DRY AND WET GYPSUM.

A small block of dry gypsum wrapped in tin-foil on bulb R; a similar block soaked in water on bulb B; the tin-foil was pierced with pin holes so as to allow only a moderate degree of evaporation.

A. M.

11:7 Battery on to balance, and then turned off so that the blocks of gypsum might be placed on the bulbs.

11:25 Battery on: the B-cool fall is owing to the evaporation and conducting power of the damp gypsum (B).

P. M.

12:14 Doors and windows of the greenhouse opened, producing the following changes:

	Dry bulb, °C.	Wet bulb, °C.	Humidity of air, per cent.
12:13 - -	15.0	12.2	70
12:18 - - -	11.3	7.8	58
12:27 - -	8.5	6.0	66
12:43 - - -	7.8	6.0	75

The air was thus cooled, and was at first rendered drier; the increased evaporation should therefore have cooled B still more, but the curve shows that it became relatively warmer; this must be due to the fact that the block of damp plaster (B) took longer to cool. It was clearly a temporary effect, since at 12:43 the curve returned to nearly the position occupied before the temperature was lowered.

At 12:43 (about) the windows and doors were shut, and a reverse movement of the same temporary character followed.

The experiment was repeated with an Alisma leaf on bulb B and the damp block of plaster on R. When the temperature fell, the leaf, in spite of its smaller volume, cooled more slowly than the plaster; there was therefore a relative warming of the leaf lasting about 15 minutes, and the reverse effect occurred as

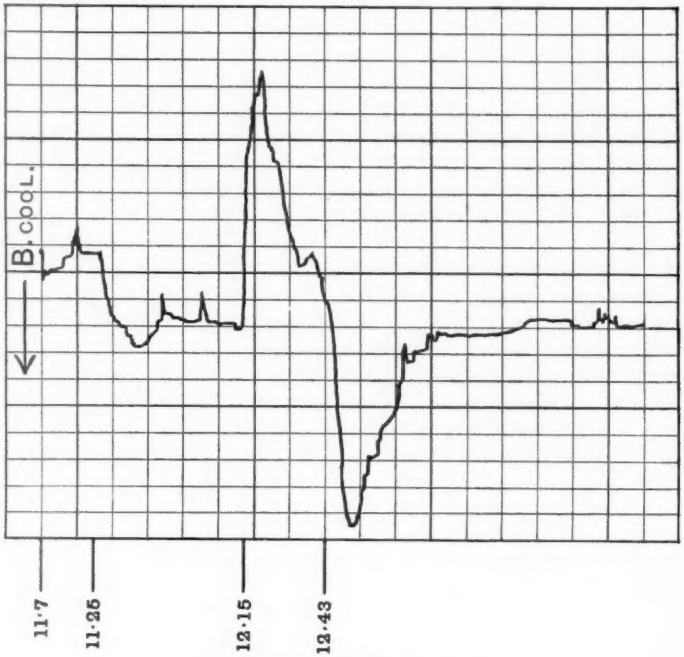

FIG. 3.—See Experiment 46, p. 85.

the air became warmer again on the door and windows being closed.

These experiments show clearly the necessity of using for the control bulb a body equaling in volume and conductivity that on the experimental bulb. A cut leaf with closed stomata answers this purpose well enough.

Another element of some importance is the condition of the air. It is obvious that, if the air becomes drier, the evaporation from the experimental leaf will increase, and the curve might be

interpreted to mean that the stomata had opened more widely. This is not of great practical importance, since the method is used chiefly to demonstrate sudden changes in the condition of the stomata. But in taking readings of the closure of the stomata occurring naturally at night, it would be necessary to take account of the effect of the dampness of the night air. One way of counteracting the error is to place on the control bulb a leaf of a species whose stomata do not close at night. Another method, which is more easily managed, is to use for a control a wet strip of linen.[6] Any change in the moisture of the air will affect both leaf and linen in roughly the same way, and thus an increase in the leaf temperature may be put down as practically all due to closure of the stomata. It should be noted that the effect of moist air is not nearly so great in a resistance thermometer as in an ordinary wet and dry bulb thermometer, no doubt because the temperature of the bulbs is maintained above that of the air. It follows that the error against which the use of a wet bulb is meant to guard is not nearly so great as might be expected.

EXPERIMENT 106. *March 14, 1901.*

Bulb B was covered with a strip of wet linen, while bulb R was exposed to the air. By watering the floor and the hot pipes, the air was made damp, as shown by the following readings:

P. M.	C.	C.	Per cent.
4:0 - - -	15.7°	12.7°	68
	Watered floor		
4:5 - -	15.8	13.2	
4:7½ - - -	15.8	14.0	83
4:12 - -	16.0	15.0	89
4:19½ - -	16.0	15.2	91
5:11 - -	14.9	12.8	77

Between 4:0 P. M. and 4:19½ P. M. the difference between the wet and dry bulb mercury thermometers decreased from 3.0° C. to 0.8°, *i. e.*, by 2.2°. If the resistance thermometers behaved like an ordinary wet and dry bulb psychrometer, the difference

[6] It must be separated by a layer of oil-silk from the surface of the bulb, lest the thermometer wire should be wetted through a crack in the varnish by which it is covered.

between their temperatures, as seen on the curve, should have diminished by 53 mm. As a fact it only diminished by 14 mm, *i. e.*, the effect as measured by the Callendar recorder is only 26.4 per cent. of the actual change. Between 4:19½ and 5:11 the difference between wet and dry bulbs increased (as the air grew drier again) from 0.8° to 2.1°, *i. e.*, by 1.3° C. This should have given a change on the recorder-curve of 31 mm. The recorded change was not at any rate more than 8 mm, *i. e.*, 25.8 per cent. of the actual psychrometer effect.

EXPERIMENT 108. *March 16, 1901.* NARCISSUS.

In this experiment the effect of damp air is shown with a Narcissus leaf on bulb R and with nothing on bulb B. The floor and hot pipes were watered, with the following result:

P. M.	Dry, C.	Wet, C.	Per cent.
2:11	17.9	12.7	52
	Watered floor and pipes.		
2:22	18.3	16.8	85
2:27	18.2	17.2	90
2:56	Opened door.		
3:1	16.8	13.5	67

Thus, between 2:11 and 2:27, the difference between the wet and dry bulb mercury thermometers decreased from 5.2° to 1.0°, *i. e.*, by 4.2°. This would mean a fall in the curve of 100.8 mm. The actual change in the curve was a drop of 22 mm, or in round numbers 22 per cent. of the psychrometer difference. The stomata were wide open throughout the experiment. Between 2:27 and 3:2 the difference between wet and dry mercury thermometers increased by 1.7°, which would equal 41 mm; the change in the curve was 12 mm, or 29 per cent. of 41 mm.

It should be added when an ordinary thermometer is converted into a wet bulb by wrapping it in a leaf, the difference between it and a dry bulb is considerably less than that between the wet and dry bulbs of a psychrometer.[7]

It is not obvious why the leaf when wrapped around the bulb of a thermometer behaves so differently from the wet gauze with which the psychrometer is covered. But the cause, whatever it

[7] DARWIN, FRANCIS, Observations on stomata. Phil. Trans. Roy. Soc. London. B. 190: 583. 1898.

is, should affect the recorder bulbs in the same way. On the whole, we may conclude that the effect of variations in the humidity of the air on the temperature of a leaf fitted to the recorder is comparatively small, especially when counteracted by the use of a layer of damp linen on the control bulb of the instrument. And this must be some advantage in experiments like the present, in which it is sought to estimate the opening and shutting of the stomata by temperature changes.

A possible source of error, in long-continued experiments, is that a leaf will transpire less in darkness than in light, quite apart from the closure of the stomata. This is believed to be due to the fact that the radiant energy absorbed by the chloroplasts is in part made evident as heat. It follows that a relative rise of temperature occurring at night might be put down to closure of the stomata, when it might in reality be due to the checking of "chloro-vaporization" by darkness. The following experiment, however, shows that this is not a serious source of error.

EXPERIMENT 102. *February 22, 1901.*

A tulip leaf (attached to the plant) was placed on bulb R, an "artificial leaf" made of wet linen on bulb B. Readings with the horn hygroscope showed that the stomata were open from 4 P. M., when the experiment began, until 10:32 P. M.; a slight closure had occurred, but the nocturnal reading corresponds to a fair amount of transpiration. The temperature of the air fell during the same period from 18.2° to 16.6°, but the relative moisture of the air remained the same, *i. e.*, 60 per cent. The reading of the resistance thermometer remained almost constant.

As far as one experiment may be trusted, it would seem therefore that darkness, apart from its effect on the stomata, need not produce any serious check to transpiration.

THE EFFECT OF WITHERING.

One of the points investigated in my work on stomata (*loc. cit.*, p. 548) was the phenomena which occur when certain leaves are severed from the plant. The first effect is that the stomata open more widely, and this "preliminary opening" is followed by a gradual closure of the stomata. This seemed a good subject for the recording method, since the effects occur rapidly,

and errors from changes in external circumstances are not likely to obscure the result.

The following diagrams give some of the results obtained. It will be seen that the effect of cutting the leaf stalk is a practically instantaneous fall of temperature, corresponding to the preliminary opening of the stomata, followed by a gradual rise toward the zero line. The results, in fact, absolutely confirm the observations made with the horn hygroscope.

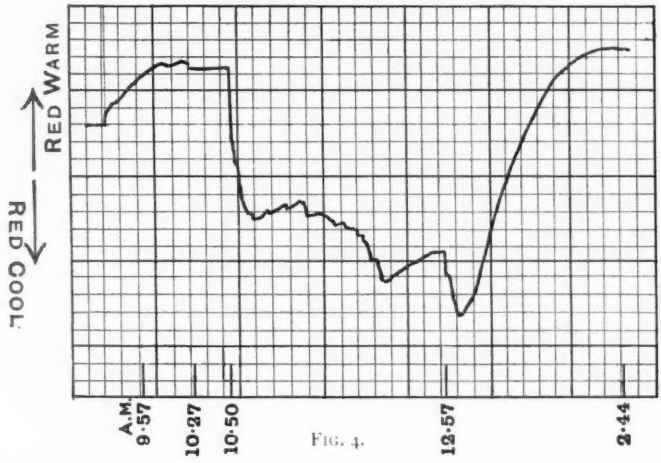

FIG. 4.

EXPERIMENT 27, *fig. 4*. *April 24, 1899*. CAMPANULA PYRAMIDALIS.

A. M.

9:57–10:27 Zero-line drawn, *i. e.* nothing on either bulb. Battery turned off and an attached leaf placed on the bulb R, a withered leaf being placed on the bulb B.

10:50 Battery turned on; the R-cool fall in the curve indicating the difference between the transpiring and withered leaf.

10:50–12:57 An irregular R-cool fall due to the stomata on the attached leaf (R) opening, as indicated by the horn hygroscope. Between 10:48 and 12:54 the moisture of the air decreased from 70 per cent. to 61 per cent., so that the whole of fall in the curve was not due to the opening of the stomata.

P. M.

12:57 Leaf on bulb R severed: a sudden R-cool fall lasting for about 10 minutes, followed by R-warm rise lasting for 1½ hours. It will be noticed that the preliminary opening of the stomata (12:57) takes place during a slight rise in the curve (R-warm) and is thus rendered distinct.

EXPERIMENT 51, *fig. 5*. *December 25, 1899*. EUPATORIUM WEINMANNIANUM.

An attached Eupatorium leaf on the bulb R; an attached Alisma leaf on the bulb B.

12:21 Eupatorium severed; rapid R-cool rise lasting 6 or 7 minutes, followed by an R-warm fall, lasting 24 minutes.

The following experiment shows the same result occurring slowly in an aquatic plant, in which class the stomata, as is well known, close much less effectively or in some species not at all, as the leaves wither.

EXPERIMENT 52, *fig. 6*. *January 16, 1900*. ALISMA.

Attached Alisma on bulb B; withered Eupatorium on R.

A. M.

10:28 B-cool fall showing difference between the transpiring Alisma and the partially withered Eupatorium leaf.

11:54 Alisma cut: an immediate B-cool fall showing opening of stomata, lasting for about half an hour, followed by gradual closure (B-warm) lasting more than 3½ hours.

The following readings of the horn hygroscope show that the Alisma stomata were not fully shut even towards the end of the period of closure. In this experiment the stomata of the Eupatorium leaf were not quite shut at the beginning of the experiment, though the low reading (10) of the horn hygroscope shows that they were nearly shut, nor were they quite shut even at 3 P. M. The withering of the leaves of this species is, I think, somewhat capricious.

READINGS WITH THE HORN HYGROSCOPE.

	Alisma	Eupatorium	Difference
A. M.			
11:53	32	10	22
11:54	Cut Alisma.		
11:56	40	11	29
12:23	40	9	31
12:42	35	9	26
P. M.			
2:11	25	8	17
2:57 } 3:00 }	22	7 (avg. of 2)	15

The difference between the horn hygroscope readings of the two leaves is given in the dotted line (*fig. 6*) and agrees fairly with the temperature curve.

It should be noted that the closure of the Eupatorium stomata would not increase but slightly diminish the long B-warm rise; on the other hand the fall of the curve from 11:54 to 12:24 is to a very slight degree increased by the change in the Eupatorium leaf during that period.

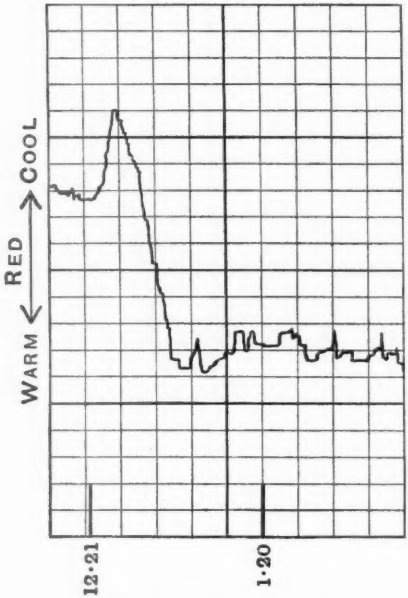

FIG. 5.—See Experiment 51, p. 91.

THE EFFECT OF DRY AIR.

Stahl[8] has published experiments from which he draws the conclusion that the closure of the stomata in dry air does not depend on the general diminution of the store of water in the leaf, but rather on the loss of water by the guard cells, which may, in his opinion, be independent of the general withering of the leaf. I have discussed this difficult question in my *Observations*,[9] where I have tentatively given the theory that the guard cells lose turgor "spontaneously," *i. e.*, "not by simple evaporation, but in response to a stimulus. And this stimulus may be the slight flaccidity of the rest of the leaf." This point of view, though it does not harmonize with Stahl's facts, has nevertheless some probability. According to my view, there must be, whenever the stomata close, a slight, though it may be an imperceptible, general deturgescence of the leaf. The repetition of certain experiments with the horn hygroscope confirms me in my belief that the first stage in the closure of the stomata is a slight general withering,

[8] STAHL, Bot. Zeitung, Einige Versuche über Transpiration und Assimilation. Bot. Zeit. **52**[1]: 121. 1894.

[9] DARWIN, FRANCIS, Observations on stomata. Phil. Trans. Roy. Soc. London B. **190**: 617. 1898.

and not a direct specialized reaction of the stomata to dryness of the air. I undertook these experiments in consequence of reading Aloi's papers,[10] with which I was unacquainted when I wrote my *Observations on stomata*. The point of Aloi's work is his proof that leaves exposed to a very dry atmosphere may have widely opened stomata, if the plants are well watered.

My experiments were carried out as follows: A plant is placed under a water-sealed bell jar, *i. e.*, in a very moist atmosphere.

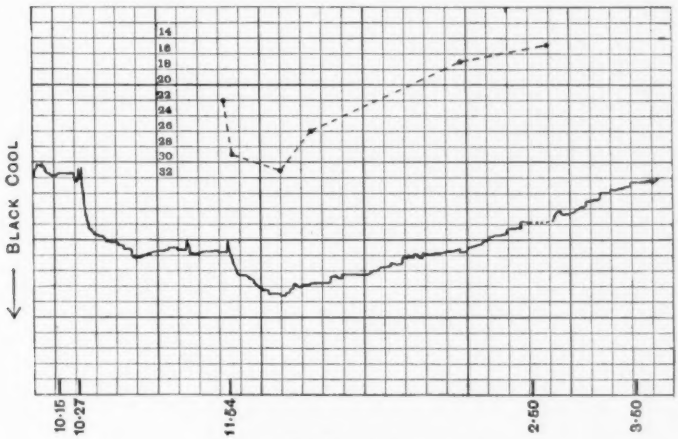

FIG. 6.—See Experiment 52, p. 91.

The bell is removed, and a reading with the horn hygroscope taken at once; the plant is then left in the dry air of a room, and it is found that the stomata gradually close, in spite of the illumination remaining practically unchanged. This is the class of experiment recorded in *Observations on stomata*. The new fact brought to my notice is that the result often fails with plants growing in well-watered soil, while it succeeds more uniformly with plants in which the soil is dry. This points to the conclusion that the closure of the stomata depends on the loss of water in the plant as a whole being greater than the intake. Analogous

[10] ALOI, La traspirazione delle pianti terrestri, etc. Catania, 1891. ALOI, Influenza dell' umidità del suolo sulla traspirazione, etc. Naturalista Siciliano 13: —. (Ni. 4-9.)

results were also obtained with the recorder (see *fig. 12*), but it will be convenient to preface them by the simpler experiments in which the condition of the soil is not taken into account.

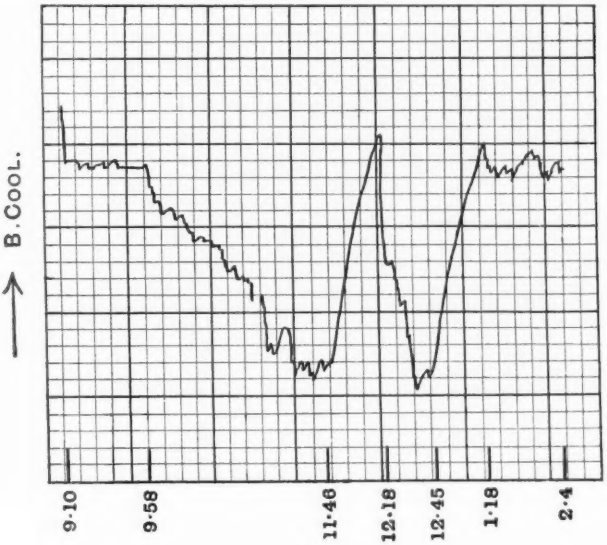

FIG. 7.

EXPERIMENT 23, *fig. 7*. *March 10, 1899*. CAMPANULA.

A. M.	
9:10	Zero line drawn.
9:58	Attached leaf on bulb R. Cut leaf (stomata shut) on bulb B.
9:58–11:46	Temperature of attached leaf on R sinks as stomata open more widely.
11:47	Plant moved from damp greenhouse (T. 19°, Psy. 78%) to dry
P. M.	greenhouse (T. 21.2°, Psy. 52.8%).
11:47–12:18	Temperature of R rises (closure of stomata).
12:18	Plant moved to damp house (T. 19.6°, Psy. 81%).
12:18–12:38	Temperature of R sinks as stomata open.
12:45	Plant moved to dry house (T. 22.9°, Psy. 51.5%).
1:18	The temperature reading practically the same as the zero line at 9:58 (*i.e.*, before the leaves were placed on the bulbs). This is also true at 12:18; the inference being that in the dry air the stomata closed so completely that the temperature of the attached leaf (R) was the same as that of the cut and withered leaf (B).

The temperature difference recorded is about 36^{mm} or 1.5° C. It must be noted that at 11:46 A. M. or 12:38 P. M. when the plant was placed in dry air the effect of such change, if the stomata were immovable openings, would be to cool the attached

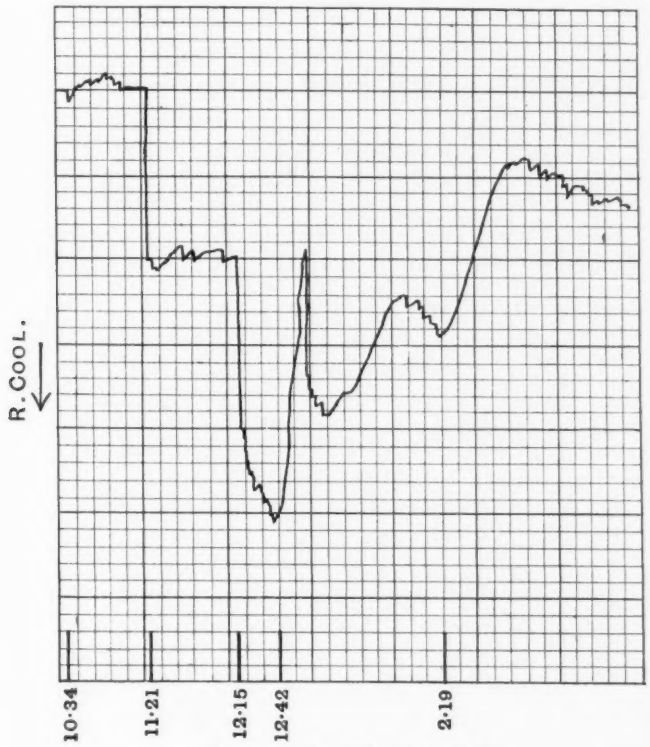

FIG. 8.—See Experiment 26, p. 96.

leaf R still more. The stomata, therefore, must have closed at once.

It may be suspected that, the damp house being some 3° cooler than the dry one, the rises of temperature at 12:18 and 12:38 were due to leaf R assuming the temperature of the air in the dry house more quickly than B. But if this were the case, the temperature curve between 1:18 P. M and 2:4 P. M. when both

leaves were left on the recorder bulbs would have fallen to what it was at 12:38, as the leaves became equal in temperature. Inequality in assuming a given temperature is a genuine source of error, as appears at p. 85, but in the present case it cannot be admitted.

EXPERIMENT 26, *fig. 8. March 21, 1899.* CAMPANULA.

A. M.

10:34–11:21 T. at 10:34 13.7°, Psy. 88%. Zero line drawn; nothing on either bulb.

11:21 T. 15.0°, Psy. 75%. Attached leaf on bulb R. Withered leaf on bulb B.

P. M.

12:16 T. 21.2°, Psy. 47%. Plant removed to dry greenhouse. The first effect of the dry air is a considerable fall in temperature (R-cool).

12:42–2:25 T. 24.5–21°, Psy. 43–48%. An irregular rise indicating a partial closure of stomata.

2:19 (T. at 2.40 21°, Psy. at 2.40 58%.) A further closure of stomata, owing probably to the darkening effect of a snow-storm.

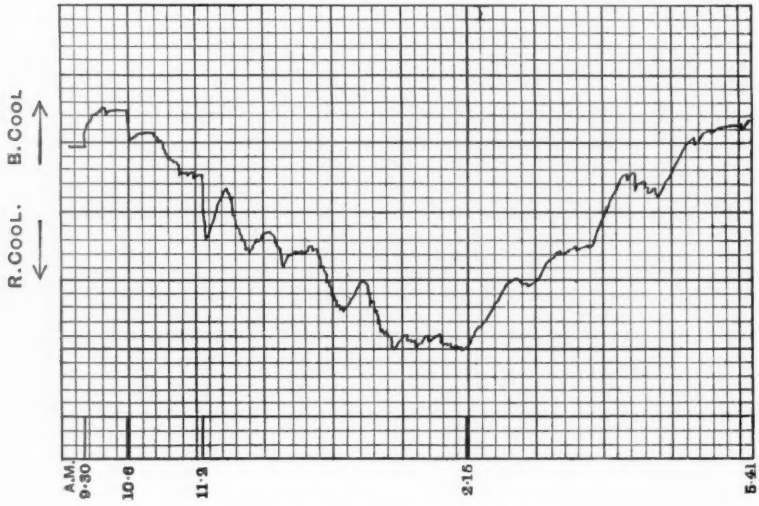

FIG. 9.—See Experiment 15, p. 97.

EXPERIMENT 15, *fig. 9. February 21, 1899.* TROPAEOLUM.

A. M.

9:30–10:6 Zero line drawn, nothing on either bulb.

10:6 Attached leaf on bulb R, withered leaf on B.

10:6 T. 12–13°, Psy. 77–78%. A gradual opening of stomata till 11:2.

11:2 Plant moved to dry greenhouse (T. at noon 25°, Psy. 40%). A sudden R-cool move, owing to increased evaporation but there was no sign of a permanent R-warm move (which would have indicated a closure of the stomata) until 2:15, although the air remained very dry, *e. g.*, at 3 P. M. Psy. 35%, T. 24.1°, and at 5:2 P. M. the psychrometer still gave 40% and the temperature was 23.5°. The rise of the curve (R-warm move) was probably due to a genuine withering of the attached leaf, though the horn hygroscope did not indicate any closure even at 3 P. M.; at 5:40 the temperature curve shows complete closure, and this is confirmed by a horn reading at 5:50.

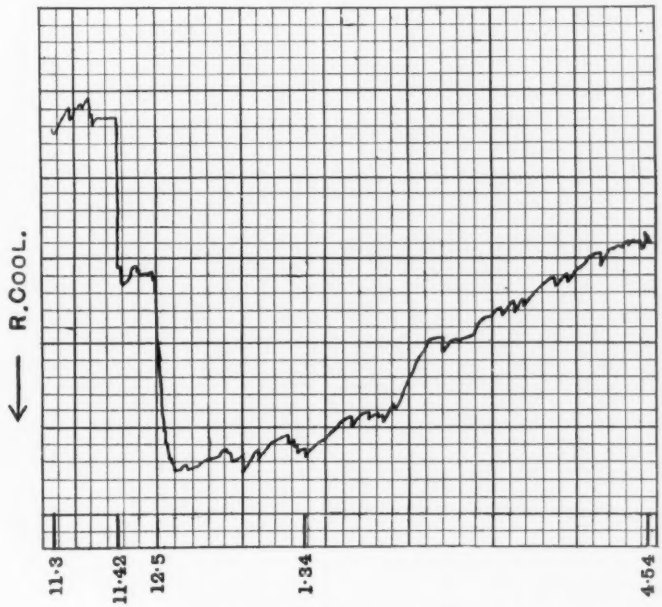

FIG. 10.—See Experiment 17 B, p. 98.

EXPERIMENT 17 B, *fig. 10*. *February 23, 1899*. NICOTIANA AFFINIS.

A. M.

11:3–11:42 Zero line (nothing on either bulb). T. at 11:8 19°, Psy. 74%

11:42 Attached leaf on bulb R, withered on B.

P. M.

12:5 Plant placed in dry greenhouse. T. 27°, Psy. 41%. Rapid R-cool move owing to the physical effect of the dryness of the air.

1:34–4:54 Gradual R-warm move, indicating gradual closure of stomata. The occurrence of closure was confirmed by horn hygroscope readings.

4:49 T. 23.6°, Psy. 37%.

EXPERIMENT 16, *fig. 11*. *February 24, 1899*. EUPATORIUM WEINMANNIANUM.

No zero line drawn, but the beginning of the curve is roughly zero.

A. M.

11:39 Attached leaf on bulb R; withered leaf on bulb B. T. at 11:35 20.6°, Psy. 71%.

P. M.

12:40 Moved plant to dry greenhouse. T. 30.8°, Psy. 40%. A rapid R-cool move, owing to physical effect of the dry air.

1:2 A rapid R-warm move, indicating partial closure of the stomata.

2:52 T. 33°, Psy. 42%. A young leaf on the plant showed signs of being withered, but the experimental leaf not visibly flagging; nevertheless it must have been suffering from want of water, as it showed no sign of opening its stomata on being placed in damp air.

Here follow two experiments on the different behavior of dry air on plants well and badly supplied with water in the soil.

EXPERIMENT 87, *fig. 12*. *July 25, 1900*. TROPAEOLUM MAJUS.

Two pots of Tropaeolum, viz., R and B; of these, plant R had been kept well watered; B had been kept without water, but was not so dry as to produce closure of the stomata.

A. M.

9:39 An attached leaf of plant R placed on bulb R. An attached leaf of plant B placed on bulb B.

10:28 The horizontal line ending here shows that the well-watered leaf R was considerably the cooler. The leaves were now removed from the recorder, and plant B placed in damp air under a bell-jar.

11:18 Plant B removed from damp air, and again placed on bulb B; leaf B, badly watered, is now cooler than it was; this can only be due to the stomata being more open; the difference cannot be due to the physical effect of the bell-jar, where, owing to the check to transpiration, it would have been warmer than leaf R, still exposed to the air of the greenhouse. T. 23–28°, Psy. 67–58%.

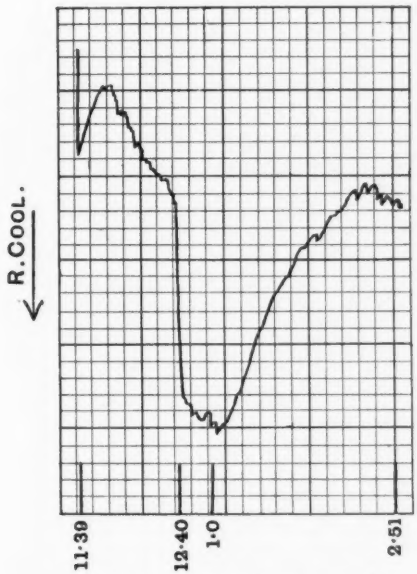

FIG. 11.—See Experiment 16, p. 98.

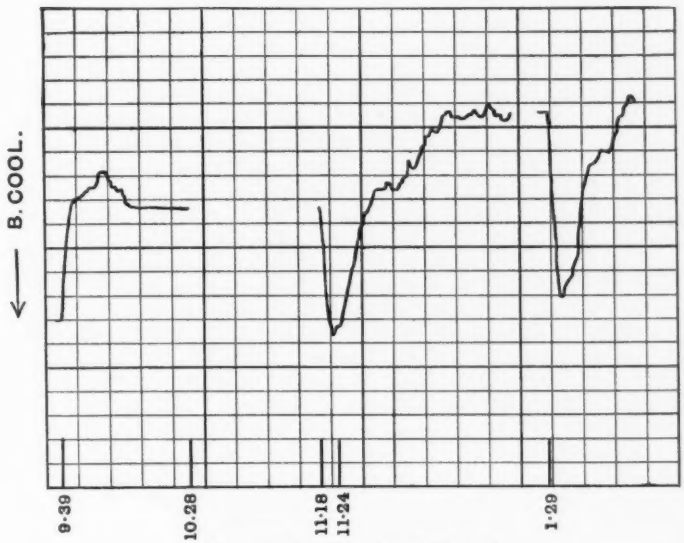

FIG. 12.—See Experiment 87, p. 98.

11:24 Sudden change, indicating a rise of temperature in B or fall in R, and as there is no reason to suppose that any change in R had taken place, the rise in the curve must be due to the closure of the B stomata in the drier air of the greenhouse.

P. M.

12:31 Plant B again placed in damp air.

1:29 Leaf B again placed on pyrometer B. Again the curve indicates that the stomata were more open and rapidly close in dry air. The opening of the stomata in the damp, and the closure in the dry air, was observed in this experiment by means of the horn hygroscope, and these approximately follow the temperature curve.

The above results were confirmed by two more observations on the same Tropaeolum plants. In both cases the stomata of a leaf on the unwatered pot B were opened by damp air. Judging by the temperature curve only, in one case the dry air produced rapid and striking closure, in the other, slow and less obvious closure.

These experiments are not thoroughly satisfactory, since both the well watered and unwatered plants should have been exposed to alternations of dry and damp air; but they show at any rate a degree of sensitiveness to such changes in the unwatered plant which I have not observed in normal plants.

COMPRESSION OF THE STEM.

It is known[11] that compressing the stem in a vise checks the transpiration current. And I have shown[12] that the checked water supply produces closure of the stomata, which apparently reopen when the vise is unscrewed. The following is a temperature record of the same experiment:

EXPERIMENT 97, *fig. 13*. *August 23, 1900*. CLEMATIS MONTANA. A branch placed with the cut end in water.

A.M.

10:23 A leaf on bulb B, an artificial leaf on R.

10:49 Vise screwed tightly to branch below the leaf.

The first effect is a B-cool move, indicating the preliminary opening observed (*loc. cit.*) with the horn hygroscope; followed by a closure of the stomata (B-warm).

[11] DARWIN, FRANCIS, and PHILLIPS. Proc. Cambridge Phil. Soc. **5**:364. 1886.

[12] DARWIN, FRANCIS, Observations on Stomata. Phil. Trans. Roy. Soc. London B **190**:555. 1898.

11:55 Vise unscrewed.
The final result is B-cool, *i. e.*, opening of the stomata; the preliminary increased closure, lasting about five minutes, I have not observed elsewhere, and is no doubt the expression of the fact
P.M. that release from compression does not at once take effect.
1:22 Vise again applied.
Preliminary opening followed by closure.
2:19 Vise removed. No effect. This no doubt is due to the vessels being so much crushed that their lumens remain closed even when relieved from compression. In a second experiment on Aug. 24, 1900 with another branch of *Clematis montana* the preliminary opening, 12 minutes, and closure, 24 minutes, were clear, but the effect of removing the vise was very slight. When, however, the branch was cut under water between the vise and the leaf, an immediate cool-move occurred.

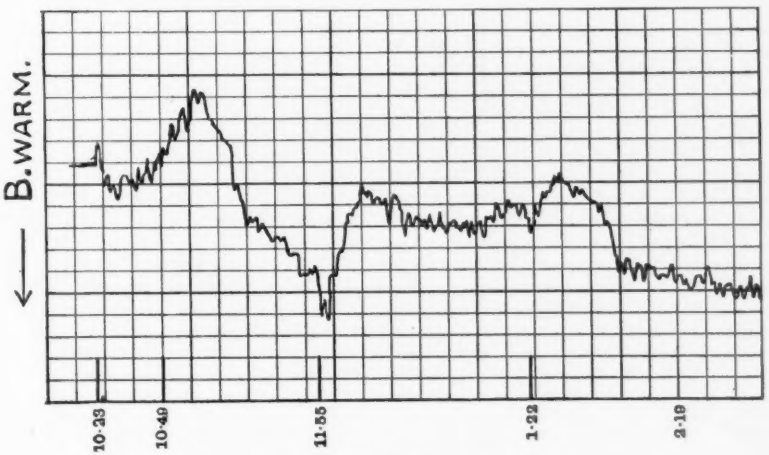

FIG. 13.—See Experiment 97, p. 100.

I have discussed (*loc. cit.*, p. 556) the question whether the increased transpiration which generally follows the relief from compression is really due to the opening of the stomata, or whether the sudden rush of water into the leaf could produce the effect, even though the stomata remained half closed. I see no way of deciding the question.

LIGHT AND DARKNESS.

I made a considerable number of experiments on the diurnal opening and closing of the stomata, using as a control either a leaf whose stomata remain open at night, or an artificial leaf made of damp linen, or a withered leaf. The curves obtained show clearly enough a lowering of the temperature at sunrise, and a rise at sunset, but I have gradually come to think the results not sufficiently trustworthy to be published, and for the present I withhold them.

ARTIFICIAL CHANGES IN ILLUMINATION.

The most interesting results were obtained by artificial darkness. In my early experiments the plan followed was to fix a large horizontal sheet of glass close above the bulbs of the recorder which were placed as near as possible to each other. By covering the glass with black cloth, a considerable diminution in illumination could be produced without any danger of altering the hygroscopic conditions of the air.

Afterwards I managed to produce a greater degree of darkness by adding a curtain, hanging down like a flounce, all round the glass plate. As long as the horizontal glass was uncovered the leaf on the recorder bulb was well-illuminated, as the experiments were made in a greenhouse. When the black cloth was drawn over the horizontal glass the light was sufficiently diminished to produce rapid closure of the stomata; at the same time the other physical conditions are not altered in such a way as to produce a difference in temperature between the two bulbs. In order to make sure that the increase in the leaf temperature (which occurs in darkness) is actually due to stomatal closure and not to purely physical effects, several experiments were made with "artificial leaves." The two bulbs, wet and dry, were placed close together under the flounced glass plate, one bulb being covered with damp linen, the other being left naked, or covered with dry paper on platinum. The effect of alternating periods of light and darkness on the relative temperature was uncertain and variable, and in this respect very different from the results obtained with living leaves. The results with artificial leaves were as follows:

Exp. 79.—There was either no effect on the temperature, or when an effect was produced it was the reverse of the leaf-effect, *i. e.*, the artificial leaf became relatively cooler in darkness, warmer in light.

Exp. 86.—No definite effect on the temperature-curve.

Exp. 89.—The effect of alternate light and darkness was perceptible, and was of the same character as in the case of leaves, *i. e.*, darkness produced a relative rise of the temperature of the artificial leaf. But the curve as a whole is strikingly different from a leaf-curve, both in the slight amplitude and the slow occurrence of temperature change.

Exp. 96.—Four alternate observations of light and darkness produced no visible effect on the relative temperature.

From these experiments I conclude that alternations of light and darkness do not produce alternations in the temperature of a layer of wet linen. This being so, we may, I think, accept the obvious explanation that the temperature changes produced in a living leaf are simply due to opening and closing of the stomata.

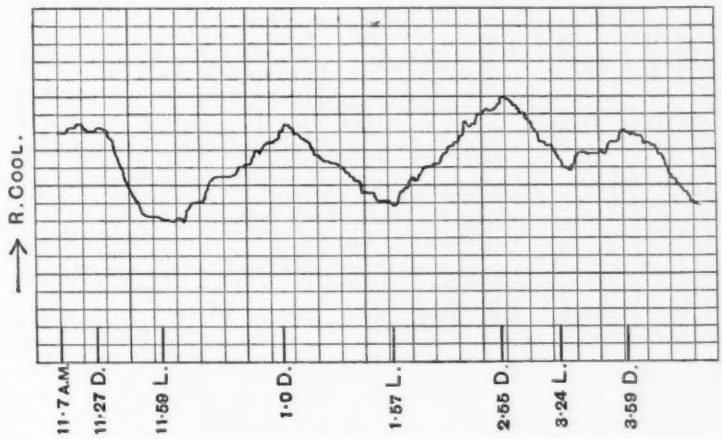

FIG. 14.

EXPERIMENT 62, *fig. 14*. *March 27, 1900*. NARCISSUS.

The leaf on bulb R, an artificial leaf on B; therefore, an R-cool rise in the curve means an opening of the stomata.

The diagram shows the times at which the illumination was

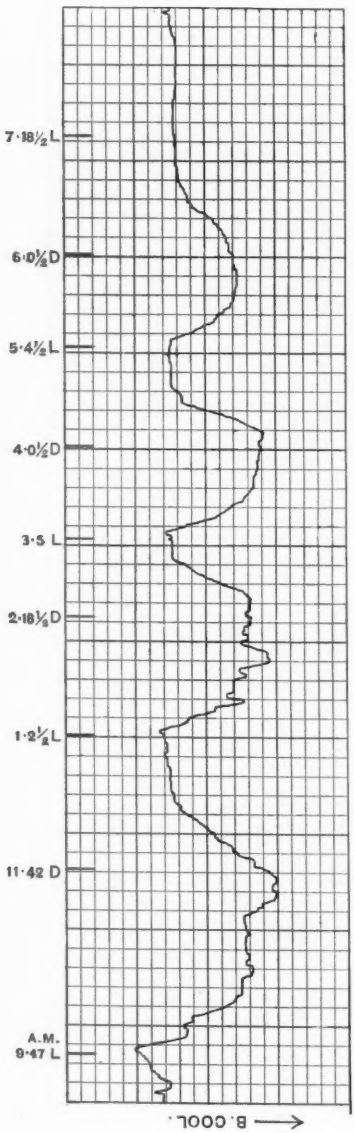

FIG. 15.

changed, D meaning that the black velvet was drawn over the glass, L that it was removed.

The first two changes at 11:27 and 11:59 A. M. take place somewhat slowly, *i. e.*, from 6 to 10 minutes after the change in illumination, but the later variations in the curve coincide very closely with the letters D and B. The R-cool change at 3:24 is smaller than the others. This is probably an instance of what is usually quite obvious, that late in the afternoon the stomata do not open when illuminated.

EXPERIMENT 77, *fig. 15*. *May 23, 1900.*
CAMPANULA PYRAMIDALIS.

Campanula on bulb B, withered leaf on R; a B-cool fall in the curve means opening stomata.

As in *fig. 14*, the letters D and L give the times at which the black velvet was replaced or withdrawn. The reaction time varies somewhat through the day, but in many cases the change in the curve follows very closely the change in illumination. At 7:19, *i. e.*, 40 minutes before sunset, the removal of the black cloth produced no effect. In my *Observations on stomata*, p. 596, I called attention to this fact, so that in this respect *fig. 15* and other similar results confirm my former work. But this refusal of the stomata to open at a time approximating to their natural hour for closing is the

only evidence of periodicity which I have obtained. It corresponds exactly to some of Pfeffer's experiments on the "sleep" of flowers.[13] On the other hand, my curves do not confirm the more detailed differences between the behavior of the stomata in the morning and afternoon, as given in my *Observations* at the foot of p. 596. This is a difficulty which I hope to clear up.

BOTANICAL LABORATORY,
Cambridge, England.

[13] Physiol. Untersuchungen. 1873.

THE ARCHEGONIUM OF MNIUM CUSPIDATUM.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LIII.

G. M. HOLFERTY.

(WITH PLATES V AND VI)

ALTHOUGH the archegonium of mosses has been much studied, the origin of the axial row and the relationships of the various members comprising it have been left in uncertainty. These points can be established best by mitotic figures, but mitosis in mosses must go on very rapidly, for figures are rare; and it is no doubt due to the infrequent observation of mitotic figures that these questions have been left so long in uncertainty and that observers have been led to different views.

For the present work material was collected at the Dalles of the Wisconsin River in Wisconsin, along the Mississisippi River in upper Iowa, near Oberlin in Ohio, at Starved Rock and in the vicinity of Chicago in Illinois. The methods used were those that have been generally approved. Since the terminology used in the various papers dealing with this subject is confusing, it may be stated that that used in this paper is largely that of Janczewski (9).

I am under obligation to Professor John M. Coulter, Professor Charles R. Barnes, and Dr. Charles J. Chamberlain for valuable suggestions during the progress of the work; and also to other members of the Department of Botany who have kindly contributed valuable material.

HISTORICAL.

In 1851 Hofmeister (1) outlined the development of archegonia and antheridia in bryophytes, showing that the earliest stages of both are identical, a fact fully confirmed in the present paper; but his view as to the origin of the axial row in the archegonium and of a similar row in the antheridium receives no confirmation.

Schimper (2), in studying Sphagnum, confirmed Hofmeister's

account of the early stages of the archegonium, but did not commit himself in reference to the origin of the axial row.

Leitgeb (**5**), in examining a few plants of Sphagnum, found a single archegonium in each, directly arising in each case from the apical cell, the first division being transverse.

Kühn (**8**) investigated Andreaea, and discovered similarity in the very earliest stages of archegonia and antheridia, but outlined the further development of the two organs very much as they are ordinarily understood today.

In 1872 Janczewski's paper (**9**) appeared, and his conclusions that concern this paper are as follows: The first divisions of the archegonium initial are exactly the same as those of the antheridium, and at this stage the two organs are not distinguishable. The cover cell does not remain inactive, but produces adventitious segments (not exceeding six) and canal initials. The inner cell (the first cell cut from the lower end of the terminal cell) divides to form the central cell and the primary canal initial, and the central cell produces the egg and ventral canal cell. The canal cells have different origins; the lower arising through transverse divisions of the primary canal initials, the remainder through the divisions of the adventitious cells.

Hy (**12**) in an extensive review of researches on the archegonium supports the views of Janczewski.

In 1895 Campbell (**13**) gives a detailed account of the development of the archegonium in *Funaria hygrometrica*, agreeing very nearly with that of Kühn for Andreaea. The cover cell acts as an apical cell, cutting off four rows of segments, three from the lateral faces to form neck cells and one from the base to form the axial canal row. The lateral segments divide by vertical walls, making six peripheral cells which later divide by transverse walls; but the canal cells, so far as could be determined, do not divide after they are first formed.

In 1897 Gayet (**15**) published observations on the development of archegonia in twenty-two genera of mosses and liverworts. His conclusions differ at two critical points from those of other observers, namely the origin of the axial row and the similarity of archegonial development in liverworts and mosses.

He finds that the archegonium in liverworts exhibits both intercalary and terminal growth; that in mosses this terminal growth contributes notably to the length of the organ, five or six adventitious segments being formed at the expense of the apical cell; that the terminal cell does not contribute at all to the canal cells, either in mosses or liverworts; that the neck canal cells all arise from an initial cut from the mother cell of the egg; that two ventral canal cells are occasionally found in Sphaerocarpus, and one such case was noted in Marchantia; and that the ventral canal cell in Marchantia is capable in rare cases of being fertilized in place of the egg.

Goebel (**18**), having examined the development of archegonia in *Mnium undulatum*, is unable to sustain Gayet's views, but corroborates those of Kühn, Janczewski, and Campbell, namely that the moss archegonium develops in part by segments (some of which are axial) cut from an apical cell; and in this regard is to be distinguished from the liverwort archegonium with its inactive cover cell.

EARLY STAGES OF THE ARCHEGONIUM.

In early stages archegonia and antheridia cannot be distinguished. Enlarged papilliform cells arise from the surface of the receptacle, and segments are cut off right and left from a two-sided apical cell (*figs. 1–10*). This method, just as characteristic for archegonia as for antheridia, agrees with Hofmeister's account (**1**), but differs from the accounts of Leitgeb (**4**), Kühn (**8**), Janczewski (**9**), Campbell (**13**), Gayet (**15**), and Goebel (**18**) in the absence of a wall that cuts off a basal cell from the archegonium initial or the archegonium mother-cell. When six to eight segments have been cut off, the two-sided apical cell is transformed into a three-sided one, a process that introduces a history distinctly characteristic of the archegonium.

The first indication of this change that marks the organ as an archegonium is seen in a division of the apical cell which results in the introduction of a curved wall more nearly vertical than that which cuts off any preceding segment. The approximately vertical position of this wall causes it to fall upon the same wall below as that which the wall immediately preceding joins (*figs.*

11, *12*). This ends the work of the two-sided apical cell and introduces that of the three-sided one, so characteristic of growing organs in the archegoniates. Leitgeb (**4**, p. 6) sought some instances of divergence by which this shift from a one-half to a one-third divergence could be explained, but without success. The transition is abrupt and not by gradual stages. The next division of the apical cell is longitudinal and cuts off a tangential segment from a middle cell. It is evident that the introduction of the last three walls constitutes the beginning of the archegonium proper, and the middle cell the beginning of the canal. All that lies below this constitutes the pedicel, which in mosses comes to be very massive (*figs. 14*, *19*, *25*, *28*) and often very long (*figs. 16*, *20*, *45*, *47*).

While the divisions of the apical cell have been in progress, transverse and longitudinal divisions have been taking place in the segments below (*fig. 12*), only two or three of the lowest segments not being thus divided (*fig. 12*), and the transverse divisions generally appearing first (*fig. 7*). Longitudinal divisions occur in the three peripheral cells, producing a neck of seven cells, a middle cell surrounded by six peripheral cells (*fig. 48*, *c*, *d*). The middle cell next divides transversely, producing a terminal cell (*t*) and an inner cell (*i*) (*figs. 13*, *14*, *18*). There is no dissent from the view that this inner cell in both mosses and liverworts is the first of the axial row and a progenitor of the egg. It divides transversely, giving rise to the central cell (*c*) (*figs. 15*, *16*, *19*, *22*) and the primary canal initial (*p*) (*figs. 19*, *22*). The central cell does not divide again until the division which gives rise to the egg and ventral canal cell, gradually increasing in size until its volume is six or eight times that of the neck cell lying next to it (*figs. 24*, *33*). The primary canal initial, on the other hand, soon divides, and with the subsequent divisions of its daughter cells helps to form the canal series. It will be seen that the development thus far is practically that of the archegonium in liverworts.[1]

[1] Compare Leitgeb (**10**), Kny (**3**), Janczewski (**9**, p. 402), Strasburger (**6** and **7**), and other observers who deal with liverworts.

THE TERMINAL CELL AND THE CANAL CELLS.

The most difficult part of the research is to determine the behavior of the terminal cell and that of the canal cells from this period. That the origin of the axial row, including the points just mentioned, is a difficult problem is evident from the conflicting accounts of those who have attempted to solve it. There is quite general agreement, however, that the terminal cell in the mosses does not cease activity after cutting off the primary peripheral cells and the inner cell, as does the cover cell in the liverworts, but continues to increase the length of the archegonium neck by cutting successive peripheral segments from its three lateral faces.

The status of the problem of the origin of the canal series may be summarized as follows: Hofmeister's (**1**) idea that the canal series arises from one of the four original pedicel rows as triangular tangential segments of its cells is mentioned only as a matter of history, the erroneous conception soon being abandoned; Kühn (**8,** p. 31) claims that all the cells of the axial row are cut from the base of the apical cell (*cf.* his diagram, *pl. 10, fig. 71*); Janczewski (**9,** pp. 412, 413) says that the numerous canal cells are of diverse origins, the lower arising through transverse divisions of segments cut from the base of the apical cell; Campbell (**13,** p. 19) says that the segments cut from the base of the apical cell constitute the axial row of neck canal cells, which, so far as could be determined, do not divide after they are first formed; according to Gayet (**15,** p. 241), all the neck canal cells have the same origin, all arising from an initial cut from the mother-cell of the oosphere, and no segments being cut from the base of the terminal cell; and finally Goebel (**18,** p. 244) holds that the moss archegonium is distinguished from that of the liverwort by its characteristic growth from an apical cell, which also contributes canal cells, figuring such a cell in a row of twenty canal cells.

Three sources are thus alleged for the canal cells: (1) the apical cell with intercalary additions; (2) the apical cell alone; (3) not the apical cell at all, but one at the opposite end of the row. Gayet alone holds the process to be like that in the liver-

worts; the others declare it to be peculiar to mosses. In the full accounts some authors state that this process of basal segment cutting ceases very early; one that it continues late in the growth of the archegonium; and a third implies this, though it is not stated. The disagreement as to time is thus as evident as the disagreement as to method.

It may be argued that the disagreement in these conclusions is to be accounted for by the fact that they are drawn from observations on different forms; yet it would seem that such a process in closely related forms would not be radically different. There seems to be no alternative but to examine the development of the archegonium in a sufficient number of forms to discover whether there is any such thing as general agreement, and as a contribution to this the record of events in *Mnium cuspidatum* is here presented.

In this species the terminal cell continues to cut off successive peripheral segments laterally (*figs. 13–20, 24, 30, 34, 37*), and these increase the length of the archegonium neck. Transverse divisions in the peripheral cells and in the canal cells go on simultaneously (*fig. 15*). The presence of mitotic figures in the same phase side by side in the two rows leaves no room for doubt on this point, and establishes the fact that part of the growth in length of both neck and canal is intercalary. The terminal cell now cuts off a second cell from the lower face. This statement rests on the presence of the mitotic figure shown in *fig. 20*. The search for a figure in this particular cell was a long one, and its value should not be underestimated, for it proves that the terminal cell contributes to the growth of the axial row. The process would seem to be unique, differentiating the mosses from all other archegoniates in this particular.

In this connection it may be stated that careful search was made in the literature bearing upon this and related points for confirmatory evidence of the relationships of the members of the axial row based on the presence of mitotic figures, but no such evidence was found. Hundreds of figures illustrating all stages of archegonial development in both mosses and liverworts were examined, but in none of them are spindles shown. Conclusions

in all cases seem to have been reached without the sure evidence of the mitotic figure.

Having shown thus that some cells are added to the axial row by segments cut from the lower face of the terminal cell, it must next be determined whether all or only part of the remainder are thus formed, intercalary divisions being the alternative. Here too the evidence of the mitotic figures will be appreciated, for if found in the row intercalary growth can hardly be questioned. Fortunately these were found, and four such cases are shown (*figs. 24, 31–33*), proving that there are additions to the row by intercalary divisions.

How long the terminal cell continues to act as an apical cell, and whether the cutting off of canal cells ceases before the cutting off of peripheral cells are questions to be asked at this point. The number of cells constituting the row is variable. That the cutting off of cells from the lower face of the terminal cell ceases early, in some cases at least, is evident from *figs. 24, 32, 33*. Here a longitudinal wall through the center of each terminal cell clearly prevents any further additions to the axial row from this source. The presence of such a wall in the terminal cell when the number of cells composing the row was only eight or ten is very common; that in *fig. 24* is exceptionally early. There is no evidence to show that addition to the row from the terminal cell continues in any archegonium later than the age indicated in *figs. 32–34*, and much to show that it does not. Goebel (**18**, p. 244, *fig. 138*, IV) reports one case where such a division has occurred in a row of eighteen or more cells, but the absence of a mitotic figure leaves some room for question.

On the other hand, the production of neck cells by the terminal cell continues till late in the development of the archegonium, but the last divisions for this purpose are always intercalary (*fig. 30*). In many cases the number of cells in the axial row is noticeably less than those in the peripheral rows which inclose the canal row. There does not appear to be any relation between neck rows and canal row in this regard, for in other cases the numbers are nearly equal, and in a few cases those of the neck rows were less than those of the axial row.

THE DIVISION OF THE CENTRAL CELL.

The division of the central cell results in many cases in two cells of nearly equal size. This is well illustrated in *figs. 26–29*, in which the ventral canal cell is nearly as large as the egg. This character strengthens the view that the difference in size and function of the egg and ventral canal cell may not always have existed. In fact, an equality in size and probably in function may reasonably be regarded as a primitive condition; and the existing inequality may be regarded as a specialization, which among pteridophytes and gymnosperms has led to a gradual reduction in the relative size of the ventral canal cell, then to the disappearance of the wall separating its nucleus from that of the egg, and finally to the entire disappearance of any vestige of the cell. Goebel (**18**, p. 242) refers to this approximate equality in size of egg and ventral canal cell in the bryophytes, saying that they are nearly equal in many cases, but that in most cases the egg is larger. He admits that the meaning of this division is not known, but since the ventral canal cell is always present, he is inclined to believe that it has some physiological rôle, and suggests the separation of the chemotactic substance for the attraction of the sperms as a probable function.

The division of the central cell is comparatively late. No case was found where division occurred before a row of seven cells had been formed (*fig. 34*), and very often eight or ten (*figs. 32, 33*). No mitotic figures for this division were found, but the position of the nuclei and the septum, and other features, are such as to leave no doubt whatever concerning the relations of these two cells. A wall separating egg and ventral canal is always present for some time after the division takes place, but not infrequently it disappeared while the remaining septa of the row were still intact.

TRANSVERSE SECTIONS OF THE ARCHEGONIUM.

All the evidence for the development of the archegonium thus far presented has been drawn from longitudinal sections. Several series of cross-sections were made, two of which are presented herewith, and from them the following conclusions are

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drawn: (1) The terminal cell is triangular in cross-section, inclosed by three peripheral cells which have been cut from it successively (*figs. 48, b, 49, a*). No mitotic figures were found, but the position of the walls and nuclei indicate their origin. (2) The three peripheral cells divide longitudinally and produce a neck of seven rows—six peripheral and one central (*fig. 48, c, d*). These divisions are not simultaneous (*fig. 49, a*) and appear early, for the neck has six peripheral cells at the level of the second nucleus, less than 0.5 mm from the apex (*fig. 48, c*). (3) The neck has two peripheral layers near the venter (*fig. 48, j*). (4) The canal is hexagonal in outline and maintains this character till the egg is formed (*fig. 48, i*), and the venter wall breaks up into many cells (*fig. 49, g*). (5) Certain large cells, lying just below the egg and having the appearance in longitudinal sections of being members of the row (*figs. 26, 27*), are found here also, but are clearly no part of the row (*fig. 48, k, l*). (6) The pedicel bears throughout its length the quadrant character given to it by the early longitudinal divisions of the pedicel segments. Beginning at the base, the development upward is through quadrant, octant, and intermediate stages to the base of the archegonium proper, where the pedicel is twelve-celled in cross-section. At this point each quadrant consists of a center cell and two peripheral cells (*fig. 49, g–k*).

THE PERIPHERAL CELLS.

From the mode of origin of the neck of an archegonium of six rows, as already described (*fig. 48, c, d*), it is evident that the cells forming any row do not stand directly over one another, but alternate spirally around it, since they are cut off successively around the apex (*cf.* Janczewski, **9**, p. 409). The longitudinal divisions which produce the six neck cells are usually followed by two or more transverse divisions in each cell, giving rise to vertical groups of four (*fig. 23*). In the early pedicel segments only one division occurs, and in some of the later segments division occurs in only one of the two cells arising from the first division, giving rise in such cases to groups of only two or three cells. The axes of these groups come later to stand in an oblique direction (*fig. 23*).

It is well known that as the archegonium approaches maturity there is usually more or less torsion of the neck. I am disposed to attribute this torsion to the alternating arrangement of the peripheral cells as a disposing cause, if not the efficient cause. Janczewski (**9**) noticed both the alternation (p. 408) and the torsion (p. 410), but did not relate them. Campbell (**13,** p. 194) calls attention to the fact that the rows are not vertical, but says that the neck cells do not stand in vertical rows, but are somewhat obliquely placed owing to the torsion of the neck during its elongation. This explanation would account for the cells not being in vertical rows, but leaves out the fact that the cells never were in vertical rows, but in oblique rows from the first, owing to the way in which they were cut from the terminal cell. A study of *fig. 19* will show that as the cells composing each group lengthen in their growth torsion must be inevitable.

THE HOMOLOGY OF ARCHEGONIA AND ANTHERIDIA.

The question of homology of archegonia and antheridia is not new. Homologies in the development of male and female sex organs and of the gametes themselves among the lower forms are well established, as mentioned by Goebel (**18,** p. 243). This has been a more difficult problem for organs as stable as archegonia and antheridia. The archegonium is highly differentiated, but maintains its form and other characters so constantly that it serves as the important structure in establishing the natural relationships of several great groups of plants. It is so different in form and function from the antheridium that attempts to homologize the two organs on general features have not been successful. Goebel (*l. c.*) admits that in the mosses very great differences in structure of the sex organs exist from the very beginning of their development, and thus implies the difficulties that lie in the way of homologizing these organs. I shall attempt to establish the homology of archegonia and antheridia by showing the homology (1) of the early stages, (2) of the cells of the axial row, and (3) of the axial row series and sperm mother-cells.

1. *Homology of early stages.*—Both organs start from papilliform superficial initials, increase in length through the alternate

divisions of a two-sided apical cell, and from these early segments a pedicel is formed. From the cells supported by the pedicels arise the sterile external wall of the gametangium, and the fertile gamete mother-cell tissue inclosed by the wall. Both organs are closed while developing, but organize special regions in which apertures appear at maturity.

2. *The homology of the axial row series.*—That the cells composing the axial row constitute a homologous series is indicated by development of the row. In the first place, egg, ventral canal cell, and neck canal cells are all closely related in origin. They are all the progeny of either a single cell cut from the truncate apex of the terminal cell (Riccia), or of such a cell and subsequent cells cut from the same region in identically the same way as the first (Musci). Again, egg and ventral canal cell are sister cells, and at the time of formation are not widely different in size or appearance (*figs. 26, 28, 29*). It appears possible even that the ventral canal cell or the lowest canal cell may function as the egg.

The theory that the ventral canal cell is an abortive egg is strongly supported by Chamberlain's account of Pinus (**17**), in which the ventral canal cell is occasionally organized as an egg and in rare cases may function as such. Ikeno (**19**) from a study of Ginkgo, and Land (**21**) from his study of Thuja have arrived at similar conclusions. Gayet (**15**) reports an instance in Marchantia where the ventral canal cell was fertilized instead of the egg, but unfortunately the specimen was not saved, nor was a figure made. My own observations on Mnium yielded a case in which the ventral canal cell had outstripped the egg in growth (*fig. 42*), and doubtless would have been fertilized in place of the egg. It is possible in cases of this nature (*fig. 42*) that the larger of the two cells may be the lowest cell of the canal row and would later have given rise to a ventral canal cell and an egg.

Another unusual case which supports this homology is seen in *fig. 43*. Here there are two eggs each with its own ventral canal cell. There can hardly be any doubt that either or both of these eggs could have functioned and produced embryos, had

fertilization taken place. There are two ways in which this phenomenon can be accounted for: first, the central cell may have divided very early, giving rise to two central cells, each of which later divided and gave rise to an egg and ventral canal cell; second, the lowest canal initial may have acted as a central cell, producing by its division an egg and ventral canal cell. Coker (**22**, p. 137) has reported and figured a similar case in Mnium, and regards the supernumerary egg as derived from the lower neck canal cell. The absence of septa is to be noted in each instance, a condition not infrequent in gymnosperms.

Campbell (**14**) figures an archegonium of Geothallus which apparently had cut off successively two ventral canal cells, and there is no wall separating the second cell from the egg. There is here the possibility that the two ventral canal cells may be the result of a division of the original ventral canal cell instead of successive divisions of the egg. This view is suggested by the position of the nuclei of the ventral canal cells, both of which are in contact with the septum.

We are disposed to attribute the vigor and consequent supremacy and potency of the egg in bryophytes, just as we do that of the lowest megaspore in angiosperms, to the advantages of nutrition, that is, it is the cell nearest the source of supply. It would be an interesting problem to determine whether by nourishing the canal cells and starving the egg the former could be made to assume the function of the latter. *Figs. 42* and *43*, as also the case in Marchantia noted, seem to suggest that they could do so. At least it is clear from the illustrations here given that there is more or less fluctuation in the origin and work of the cells of the row, and that under certain conditions other closely related cells may do the work of the egg. The cases enumerated seem to furnish sufficient evidence to support the view that the cells of the row are homologous.

3. *Homology of the axial series and sperm mother-cells.*—Another line of evidence indicating the homology of archegonia and antheridia is offered by a number of abnormal forms that constitute a series lying between normal archegonia and antheridia. Bisexual organs are by no means rare. That egg and sperms can

develop in the same gametangium (*fig. 40*), which combines the form, structure, and mode of development of the two sex organs, certainly shows a close relationship between the organs which ordinarily produce egg and sperms separately. We have seen how close is the relationship between the members of the axial row. The central cell and the primary canal initial are sister cells; the division of the former produces two sister cells—egg and ventral canal cell—and the division of the latter also produces two sister cells—canal cells. We find, further, that the second pair may with other canal cells divide longitudinally and produce two canal rows (*figs. 35–37*). An organ of this nature, with its egg and ventral canal cell, with its double-walled venter and single walled neck, must still be looked upon as an archegonium, even if it has deviated slightly from the type. But when the canal members break up by successive divisions until we have an organ such as that shown in *fig. 40*, where the canal row is lost in sperm mother-cells; or that in *fig. 45*, where the egg is lost, but other members of the canal series are retained as a row, we can no longer regard the organ as an archegonium, but must look upon the first (*fig. 40*) as a bisexual organ and the second (*fig. 45*) as a modified antheridium. It will be seen that these three forms—modified archegonium (*fig. 37*), bisexual organ (*fig. 40*), and modified antheridium (*fig. 45*)—constitute a progressive series leading from the normal archegonium to the normal antheridium.

In addition to the abnormal forms already mentioned, two important cases of the apparent conversion of archegonia into antheridia have been reported from different parts of Europe by Lindberg (**11**) and de Bergevin (**20**). In these cases, which are quite similar, a radical change in the life-history of the organs appear. Each organ begins its development with the characters of an archegonium, but closes it bearing the evident characters of an antheridium. De Bergevin gives no sections of the organs, but only a series of external views representing a normal antheridium, an archegonium, and various club-shaped organs leading up to a second antheridium more than twice the length of the first. He speaks of the process as an interconversion of the sex

organs. It is doubtful if we should look upon this as a conversion of an archegonium into an antheridium, but rather as the development of a bisexual organ, or a modified antheridium.

These cases seem sufficient to establish the homology of antheridia and archegonia, and point to their derivation from a structure in which eggs and sperms had not yet been differentiated. As an illustration, attention may be called to the fact that in Selaginella the microsporangia and megasporangia are differentiated from primordia which are doubtless indifferent and capable under suitable conditions of producing either kind of sporangium. In this case the microsporangium has deviated less from the structure of the hypothetical sporangium of the homosporous ancestor. Mnium furnishes an illustration of an analogous process, the probably indifferent primordia differentiating into antheridia and archegonia, the antheridia deviating less from the structure of the hypothetical ancestral gametangium. Here, as in Selaginella, the organ which has become most profoundly modified contains vestigial structures which indicate its ancestry and the method by which it has become modified.

THE ORIGIN OF THE ARCHEGONIUM.

The origin of the archegonium and its development into the distinct female organ has never been satisfactorily worked out. There has been some attempt to relate it to the oogonia of Chara or Coleochaete, but no serious claim could now be made for this. To derive the bryophyte antheridium from that of some member of the Chlorophyceae would seem to be a less difficult task.

Barnes (**16,** pp. 277–290) has distinguished between simple and compound spermaries and ovaries, using these terms to designate sperm-producing and egg-producing organs, the simple organs being confined to algae and fungi. The compound spermary could be derived from the simple one by the formation of walls at the time the sperm cells are organized, and by the sterilization of an outer layer of sperm mother-cells for protection. The latter process would be a most natural one in case the plant was forced to change from an aquatic to a terrestrial habitat. In lectures on the bryophytes at the University of Chicago, Barnes has suggested the derivation of the arche-

gonium from some form of primitive compound gametangium. In such a case, by sterilization, a protective wall was secured and the number of gametes greatly reduced, perhaps to a single row as the form took on terrestrial habits. Barnes (**16,** p. 289) regards each member of such a central row as the homologue of a simple ovary. These undergo sterilization from the apex downward, a natural consequence of conditions of nutrition when the eggs are retained in the ovary. Such a process of progressive sterilization would not occur in the antheridium since the formation of a large number of simple sperms is the function, and with this effected the work is done. The egg, on the other hand, must provide for the development of the young sporophyte and requires an abundant store of food for this purpose.

Recently Davis (**23**) has proposed a theory for the origin of the archegonium that has very much in its favor. Because there seems to be no organ among the heterogamous algae from which the archegonium could have arisen, Davis goes to the lower Phaeophyceae for a type to illustrate his views. He takes the asexual plurilocular sporangium of certain Ectocarpaceae as a starting-point. From the asexual zoospores of such an organ sexual gametes arise through differentiation. With sexuality established, the gametangia differentiate until organs are reached from which archegonia and antheridia can be produced by processes already indicated. The aperture at the apex of each organ is significant, and the sterilization of all the gamete mother-cells but one a great advantage to the egg. Davis goes a step further and records that under certain conditions, *Schizomeris Leibleinii* and Draparnaldia have developed zoospores in organs that strikingly resemble plurilocular sporangia; and he is disposed to look upon these structures as forerunners of well-differentiated plurilocular sporangia in the Chlorophyceae.

These views of Barnes and Davis seem to be in the right direction; though it is understood that in any case it is necessary to assume the existence of heterogamous Chlorophyceae of which we have no knowledge at present. Since these views have been advanced considerable evidence in their support has been accumulating, and several cases in Mnium, described in

the preceding pages, would seem to support them. The modified organs just discussed (*figs. 36, 37, 45, 46*), and the archegonia taking on antheridial characters in their development reported by Lindberg (**11**) and de Bergevin (**20**), I interpret as indicating that the archegonium is the more specialized of the two organs, and that its atavistic tendency is toward the sporangium-like form and structure of its ancestor. It is natural, since the antheridium is less differentiated, that this atavistic tendency of the archegonium should express itself by first taking on antheridial characters. This it does by its reduced row breaking up again into gamete mother-cells (*fig. 40*); by the neck enlarging (*fig. 40*, also de Bergevin **20**); by its wall tissue becoming chlorophyll-bearing; by the loss of egg and ventral canal cell (*figs. 45, 46*); and by its assuming a general antheridial aspect. A vestige of these processes is also seen in very many archegonia where the expanded apical regions inclose masses of indefinite cells. The explanation offered for the appearance of these expanded apical regions has been that they arose on account of the stretching in a tangential direction of the peripheral cells (Janczewski **9**); but I interpret this as nothing more than an expression in every archegonium of this atavistic tendency. This view of the occasional partial atavism of archegonia expressing itself in antheridial characters bases itself upon the common origin of the two organs from a primitive organ of a sporangial nature, and upon the demonstrated homology of archegonia and antheridia.

SUMMARY.

1. The receptacle is flat-topped with many papilliform cells on its surface, which give rise to archegonia, antheridia, and paraphyses.

2. Archegonia arise from single superficial cells not distinguishable at first from those which give rise to antheridia.

3. The first two divisions of the archegonium initial are oblique and give rise to a two-sided apical cell.

4. The succeeding divisions up to as many as six are from the faces of this two-sided apical cell, archegonia and antheridia agreeing in this regard.

5. Longitudinal radial divisions follow in these segments and form a pedicel of four rows.

6. In the young archegonium the two-sided apical cell gives place to a three-sided one which is truncate.

7. This terminal cell divides transversely soon after its formation, giving rise to the first cell of the axial row.

8. The terminal cell adds to the growth of the neck by segments cut from its three lateral faces, and to the growth of the axial row by segments cut from its truncate face.

9. Growth in length of the archegonium neck is intercalary as well as apical in both the neck and canal rows.

10. The canal series is not always a single straight row, but sometimes double for a greater or less distance.

11. The peripheral cells are not in vertical rows, but alternate with preceding cells; and torsion is a consequence of this feature.

12. The egg and ventral canal cells are often of nearly equal size.

13. The cells of the axial row are homologous with each other and with sperm mother-cells.

14. Archegonia and antheridia are homologous structures throughout.

15. The breaking up of the axial row into sperm mother-cells is an expression of partial atavism on the part of the archegonium.

16. The mass of indefinite cells in the apex of the archegonium neck is the vestige of this atavistic tendency on the part of the archegonium.

17. Archegonia and antheridia probably had a common origin. Hypothetically, the structure from which they have been derived was an asexual multilocular terminal zoosporangium of some primitive extinct member of the Chlorophyceae; the course for the archegonium being through a gametangium possessing more than one functioning gamete.

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EXPLANATION OF PLATES V AND VI.

The figures were all made with an Abbé camera. The lenses used were Bausch and Lomb 1 and 2-inch oculars and $\frac{1}{6}$ objective, and Leitz $\frac{1}{12}$ oil immersion. The plates have been reduced one-half in reproduction, the magnification before reduction being 930, except for *figs. 45–47*.

FIGS. 1–10. Archegonium initial and pedicel segments.

FIG. 1. Papilliform archegonium initial rising above the surface of the receptacle.

FIG. 2. After first division, showing first wall oblique.

FIG. 3. Second wall laid down, forming the two-sided apical cell (*X*).

FIGS. 4–7. Successive stages in ditomic segmentation up to the introduction of the eighth wall; segment cells (*s*) dividing.

FIGS. 8–9. Lateral views of the archegonium initials represented in *figs. 2* and *4*.

FIG. 10. Lateral view of a young archegonium after vertical radial division of the pedicel segments, *cf. fig. 49, p*.

FIGS. 11–22. Showing origin of archegonium mother-cell and other members of the axial row.

FIG. 11. Young archegonium showing first peripheral cell (*r*) cut from archegonium mother-cell (*m*); this division is the first character clearly distinguishing the young archegonium from the young antheridium.

FIG. 12. Young archegonium farther advanced; the archegonium mother-cell (*m*) has divided, giving rise to the terminal cell (*t*) and the inner cell (*i*).

FIG. 13. Young archegonium, lateral view; inner cell (*i*) and second peripheral cell (*r*) cut off.

FIG. 14. Young archegonium; prophase of mitosis in inner cell (*i*).

FIG. 15. Young archegonium; metaphase of mitosis in both the peripheral (*r*) and inner cells (*i*).

FIG. 16. Young archegonium; metaphase of mitosis in inner cell (*i*).

FIG. 17. Young archegonium showing primary canal cell (*p*) and central cell (*c*) resulting from division of the inner cell.

FIG. 18. Young archegonium; same stage as that shown in *fig. 13*.

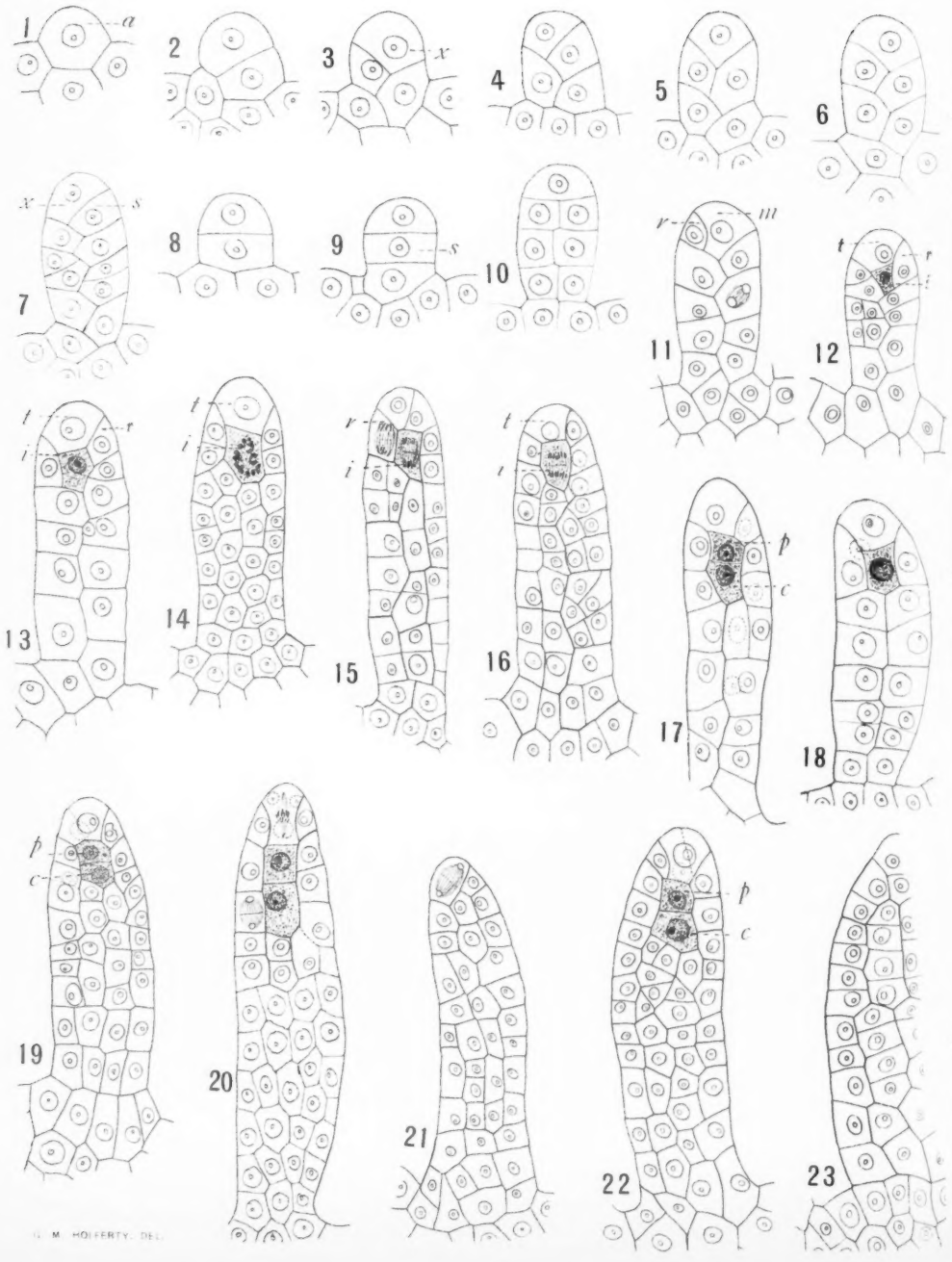
FIG. 19. Young archegonium; same stage as that shown in *fig 17*, but with pedicel farther developed.

FIG. 20. Young archegonium showing mitosis in terminal cell preparatory to cutting off the second canal cell; this feature distinguishes the moss archegonium from all others.

FIG. 21. Young archegonium showing transverse division in a peripheral cell; the section in this region is tangential, not diametral.

FIG. 22. Young archegonium showing increase in size of central cell and progressive work of terminal cell.

FIG. 23. Tangential segment from young archegonium; each peripheral cell has divided once; a second division has occurred in most of resulting cells; torsion of neck probably due to this arrangement of groups.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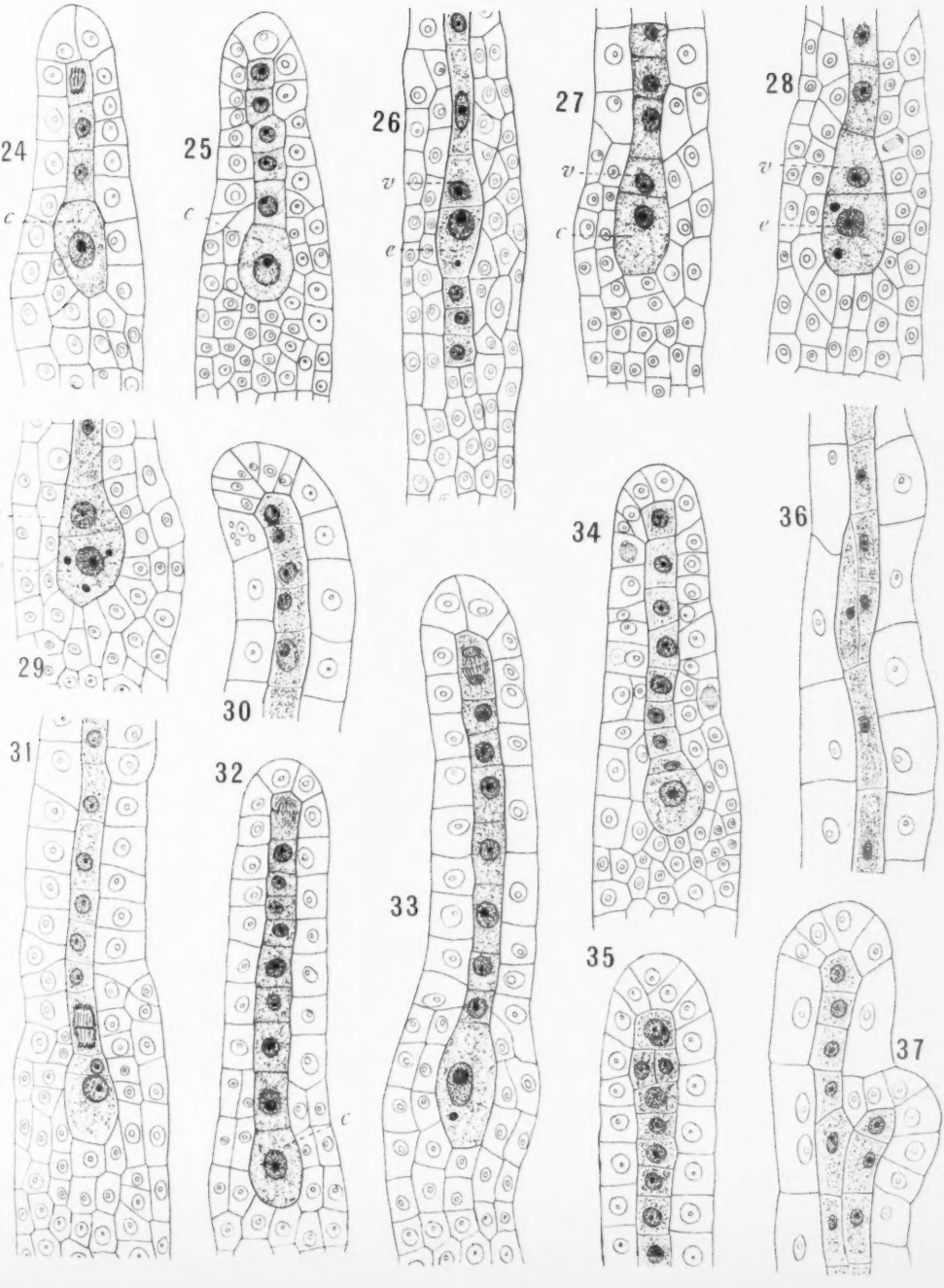
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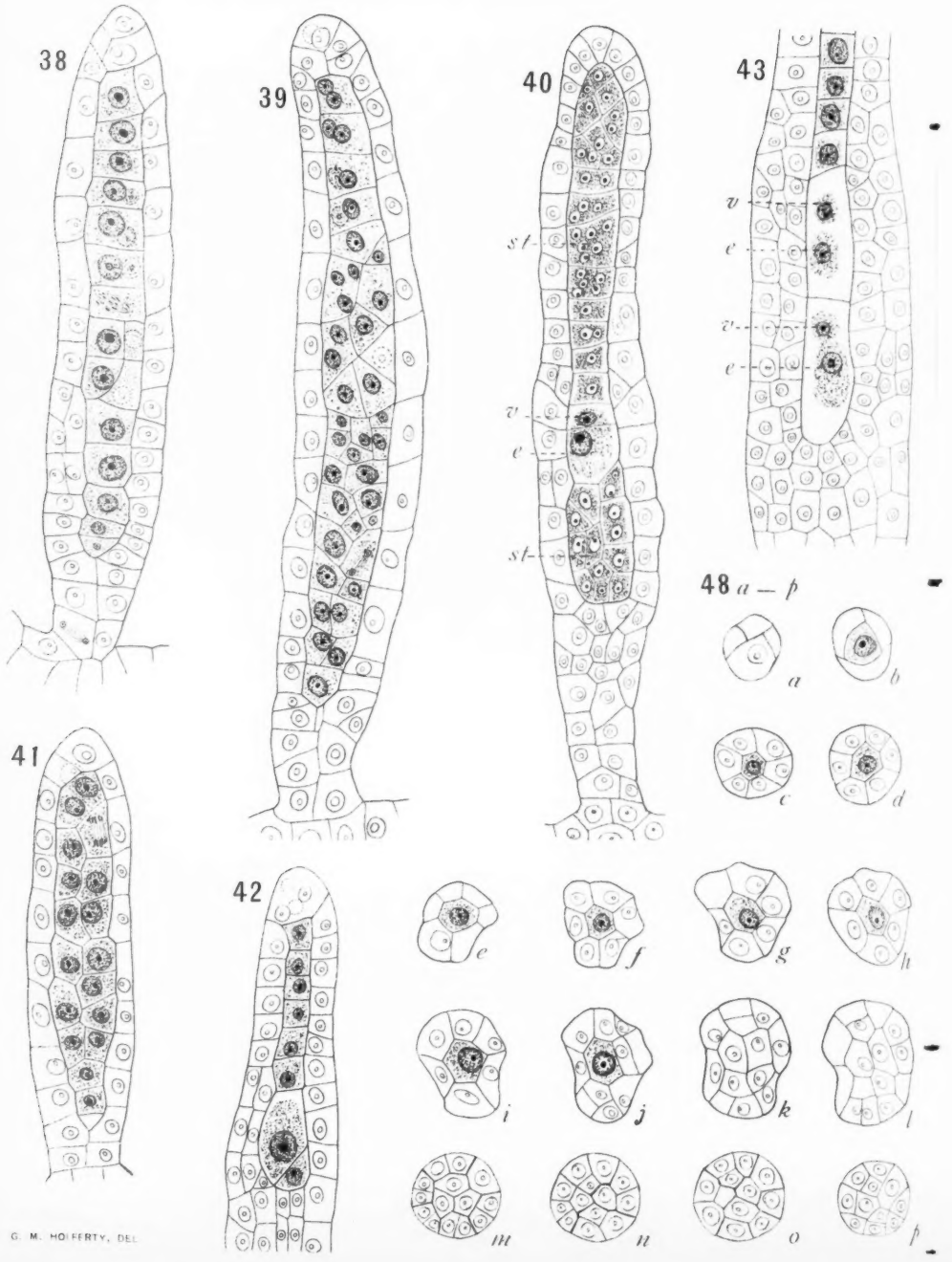
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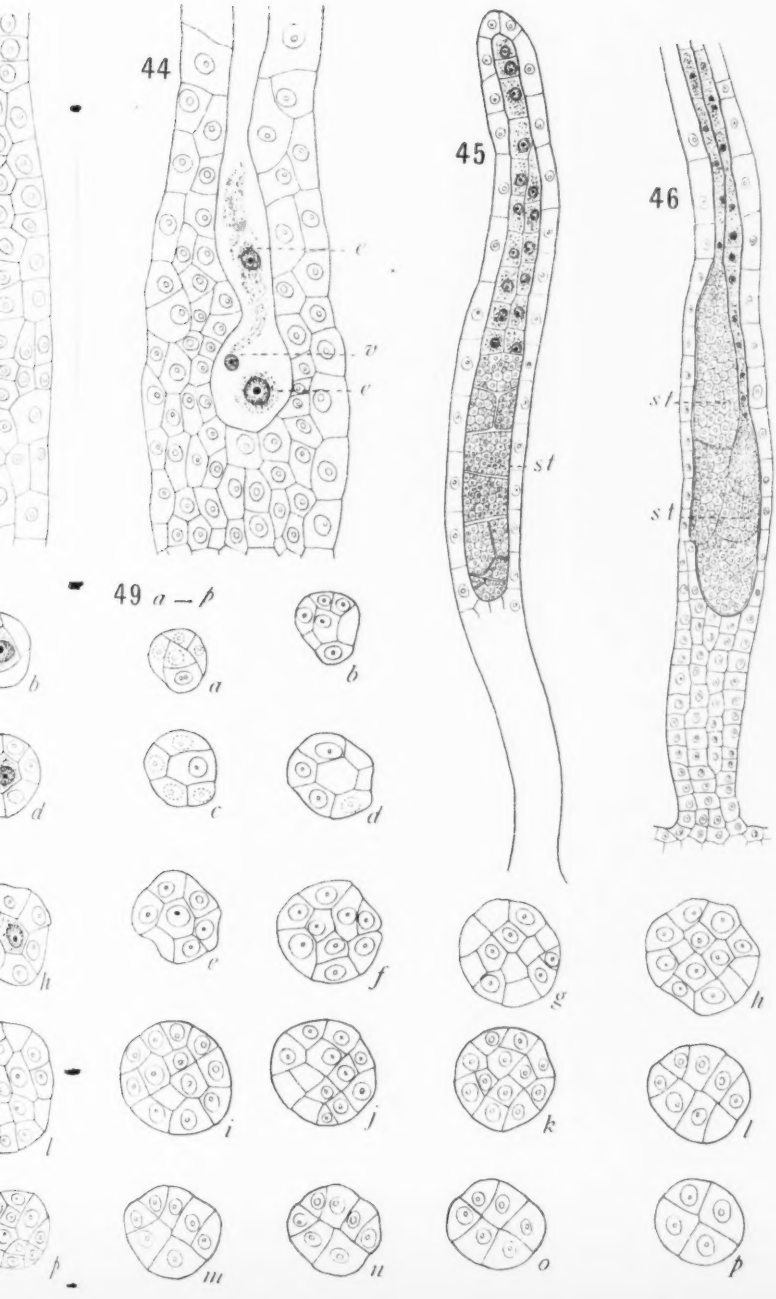
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FIG. 24. Archegonium showing division of third canal initial and rapid increase in size of the central cell; basal work of terminal cell apparently closed.

FIG. 25. Archegonium showing axial row affected by method of peripheral segment cutting (see *fig. 23*); work of terminal cell not finished; venter double walled, pedicel very massive.

FIGS. 26–29. Venters after recent division of the central cells; eggs and ventral canal cells of nearly equal size; egg cells showing masses of chromatin thrown off into the cytoplasm — an occurrence quite common for eggs, less so for ventral canal cells; evidences of a row below the egg in *figs. 26–28*.

FIG. 30. Tip of a mature archegonium, showing that last divisions in both neck and axial row have been intercalary.

FIG. 31. Venter with egg and ventral canal cell; lowest canal cell dividing showing that intercalary growth takes place after the cutting off of the ventral canal cell.

FIGS. 32–33. Young archegonia with remarkably large canal cells; central cells not yet divided; intercalary divisions taking place in last cells of the axial rows; both mitotic figures show bodies resembling centrospheres; basal segment cutting of apical cells completed.

FIG. 34. Egg and ventral canal cell, and seven canal cells; no division of central cell found earlier; upper canal cell appears to be produced by the terminal cell; longitudinal division of terminal cell prevents further basal segment cutting; intercalary growth of neck in progress as shown by mitotic figures; venter double-walled to an unusual distance above the egg.

FIG. 35. Young archegonium slightly abnormal, showing beginning of two axial rows near apex.

FIG. 36. Part of neck of an old archegonium, showing two axial rows for a short distance.

FIG. 37. Tip of an abnormal archegonium having two axial rows, each with its own apex and apical cell.

FIG. 38. Young antheridium modified by the possession of archegonium characters; the members of an evident axial row are separated by transverse walls; these cells dividing to form two rows; the double wall in the lower part and the two undivided large cells opposite to it are indications that this specimen might have produced a bisexual organ of the nature of that shown in *fig. 40*.

FIG. 39. Young antheridium further advanced; the double axial row with transverse walls are archegonium characters.

FIG. 40. A bisexual organ with evident archegonial and antheridial characters; the egg, ventral canal cell, and adjacent canal cells; the divisions to form a double-walled venter; the elongated pedicel and the terminal cell are undoubted archegonial characters; the oblique and irregular primary

walls and the spermatogenous tissue are antheridial characters; several similar organs were found.

FIG. 41. A young normal antheridium; in mature antheridia distinct regions of spermatogenous tissue can be detected representing each of these primary cells.

FIG. 42. A young archegonium with a cell cut from the lower part of central cell; whether the larger cell represents the ventral canal cell and the smaller one the egg could not be definitely determined.

FIG. 43. A venter containing two eggs and two ventral canal cells; whether the upper cell is the lowest canal cell divided or the original ventral canal cell divided could not be determined.

FIG. 44. A double venter with two eggs; all cross walls have disappeared.

FIGS. 45–46. Abnormal antheridia; in each case the mass of spermatogenous tissue is separated by the primary walls into distinct regions characteristic of antheridia; each organ has an outlet of two axial rows which before reaching the apex becomes one row; in *fig. 46* there are two masses of sperm tissue, each with its own axial outlet; the pedicels and necks are distinctly archegonial characters.

FIG. 47. A modified archegonium with traces of two axial rows, and a mass of sperm mother-cells developing in the elongated pedicel.

FIG. 48, *a–p*. Cross-sections of an archegonium from the terminal cell to the lower part of the pedicel; the middle cell and the three peripheral cells cut from it shown in *b*; the central cell and double wall of venter are shown in *j*; and the quadrate character of the pedicel in *n* and *o*.

FIG. 49, *a–p*. Cross-sections of an archegonium from terminal cell to base of pedicel; the massive character of pedicel shown in *f–i*; the four basal cells not divided (*p*).

STUDIES ON SOME ANOMALOUS DICOTYLEDONOUS PLANTS.

CHARLES E. LEWIS.

(WITH PLATES VII AND VIII)

HISTORICAL.

SEVERAL genera commonly referred to the dicotyledons differ from the typical ones both in the structure of the flower and in the form and arrangement of the vascular bundles. Among these anomalous dicotyledons are certain Nymphaeaceae, Ranunculaceae, and Berberidaceae, which have been referred to dicotyledons chiefly on account of the structure of the mature embryo.

The striking resemblance of the Nymphaeceae to the Alismales, which are typical monocotyledons, has led to the study of the development of the embryo in certain genera of the former in order to determine the origin of the structures found in the mature embryo. The first work of this kind was done by Lyon (1901), who investigated the development of the embryo of Nelumbo. He found that the two large fleshy bodies of the mature seed seemed to be lobes of a single cotyledon which has its origin as a crescentic ridge of tissue, partly surrounding the plumule and later bifurcating to form what appears as two cotyledons.

Cook (1902) published the results of a study of the embryo sac and embryo of *Nymphaea advena* and *Castalia odorata*. He describes the embryo as monocotyledonous and agrees with Lyon that the Nymphaeaceae should be regarded as monocotyledonous.

In a paper which appeared a short time after that of Lyon, Campbell (1902) calls attention to the affinities of certain anomalous dicotyledons. It is pointed out that the embryo of the mature seed and the seedlings of certain Ranunculaceae and Berberidaceae, as observed by Lubbock and Holm, show the petioles of the cotyledons grown together where the edges are

in contact, thus forming a tube which extends down to the plumule and in some cases is quite long. In the light of Lyon's work on Nelumbo, the tube surrounding the plumule suggested to Campbell the possibility of a like origin of the cotyledons in these forms and a lateral origin for the plumule as in monocotyledons.

In the light of these facts, and because of our limited knowledge of the embryology of the so-called anomalous dicotyledons, it seemed desirable to study the embryology of several of these forms.

As the Berberidaceae include peculiar and varied plants, many of which differ widely from the typical Berberis, it was decided to begin work on certain representatives of that family, in which it seems that little of importance has been done on the development of the embryo. Holm (1899) has traced the development of *Podophyllum peltatum* from the seedling to the flowering plant, and both Dickson and Lubbock have observed the seedlings of *Podophyllum Emodi*, the Asiatic form. All agree in the description of a long cotyledonar tube with a very small plumule at the bottom, and that the cotyledons are peltate in form, the two together resembling the single leaf of the second year. Holm makes the statement that the cotyledons really represent a single leaf of this plant.

COLLECTION AND METHODS.

Material for all stages in the development of the embryo of *Podophyllum peltatum* and *Jeffersonia diphylla*, together with ripe seeds for germination, were collected during the spring and summer of 1902. The stages of *Caulophyllum thalictroides* important for this study were also secured. The material was fixed in 1 per cent. chrom-acetic acid, washed and brought into 70 per cent. alcohol, where it remained until ready for use. In the older seeds the outer seed coats were cut away in order to allow the fixing fluid to penetrate the tissue of the embryo. The sections were stained with safranin, Bismarck brown, gentian, and orange G. In this manner all morphological and cytological details are clearly brought out.

PODOPHYLLUM PELTATUM.

The mature embryo sac does not differ in any important particulars from that of typical angiosperms. The fecundated egg cell increases appreciably in size, becoming slightly elongated. The first division wall is transverse, and the two cells thus formed elongate rapidly, especially the one which is to form the suspensor. At this stage (*fig. 1*) one synergid is still to be seen near the embryo, but it does not persist for any length of time, as it was not observed in older stages. At this time several endosperm nuclei are seen scattered about within the embryo sac. The antipodal cells are distinct, but they soon begin to disintegrate and are not found in the stage represented by *fig. 5*.

The eight-celled embryo (*fig. 2*) is club-shaped, and the suspensor is rather long, consisting of two or three cells. The body of the embryo soon becomes broadened (*fig. 3*), and at the stage shown in *fig. 4* it is almost spherical. Growth now takes place most rapidly in the longitudinal direction, and at the same time the suspensor becomes somewhat thickened, its cells dividing longitudinally (*figs. 5, 6*). The embryo may now be well described as pear-shaped, although there is some variation in form at this stage. In some cases one side seems to grow more rapidly than the other, and an unsymmetrical form results (*fig. 6*). From the study of a large number of preparations, both longitudinal and cross-sections, it is highly probable that *fig. 5* represents the typical shape of the embryo shortly before the beginning of the development of the cotyledonar primordium. At this time the endosperm fills the entire embryo sac, except a small cavity around the embryo, which is partly filled by material from broken-down endosperm cells.

The origin and development of the cotyledons is peculiar. In typical dicotyledons the cotyledons are supposed to have their origin as two entirely separate and opposite ridges of tissue, standing at the same level, at the broadened distal end of the embryo, so that if cross-sections be made through the base of the cotyledons they would be separate at both sides in the first section in which they appear. Although this mode of origin has been assumed by certain writers, it seems that comparatively

little has been done in the investigation of the origin of the cotyledons in the typical dicotyledons, especially by the use of series of cross-sections which are often indispensable in getting the correct orientation of parts. It may be that in many so-called typical dicotyledons there is much variation from what has been described as the accepted origin of the cotyledons. This can be determined only by a thorough and detailed study of a large number of forms.

In Podophyllum the primordium of the cotyledons appears first as a rather broad outgrowth from the margin of the truncated distal end of the embryo, forming an almost complete ring. This is made clear by a series of cross-sections such as *fig. 6*. In this figure *a* and *b* are sections through the broad part of the embryo just beneath the primordium of the cotyledons; *c*, through the plumule and the base of the ridge; *d–l* include the remainder of the cotyledonar primordium. From this figure it is apparent that the cotyledons arise as a single primordium which consists of a circular ridge broken at one side by a notch or indentation. As soon as the ridge has attained a little height, a notch is formed on the opposite side, and we have now two divisions or lobes which will develop into what are considered as two cotyledons. The figure shows that one lobe is slightly longer than the other; but this is not of importance, because in other preparations the two were found frequently to be of equal size.

A later stage is shown in *fig. 7*. The bottom of the first notch together with the cotyledonar primordium has undergone intercalary growth, so that a very short tube has been formed. This series shows that both the ridge and the lobes have increased in height, but the lobes have grown the more rapidly, because their height is now about equal to that of the ridge (compare *fig. 6*), and are of equal size. The open ridge is more prominent at this time than in younger or older stages, the notch first formed being about twice as deep as the other. The edges of the ridge are in contact below, but above they are separated. The growth of the tissue at the bottom of the first notch goes on more rapidly than that at the bottom of the second notch, so that the two tend to become equalized. This greatly increases the length of the

cotyledonar tube. *Fig. 8* represents a series of sections from an embryo a little older than the one represented by *fig. 7*. Only alternate sections were drawn. This series makes apparent the great increase in the length of the tube and the almost equal depth of the bifurcations. It seems that the bifurcations do not become of exactly the same depth at any time, as an examination of a number of series from mature embryos did not show them more nearly equal than they are in the stage represented by this figure.

It is very necessary to use series of cross-sections in tracing this development. Median longitudinal sections at right angles to the plane of bifurcation of the cotyledonar ridge present the appearance shown in *figs. 10, 11, 12*, and cannot be distinguished from similar sections of a typical dicotyledon. The ring of tissue and its two divisions increase greatly in length. There does not seem to be a localization of growth in the lobes here, as described for Nelumbo, but the ring itself grows at about the same rate as its two lobes. A narrow opening extends down to the growing point of the stem. The opening is conical just above the plumule, but for most of its length the walls of the tube are in contact.

The hypocotyl is short, and the plumule is but little developed in the mature embryo. The growing point of the stem shows simply a slight protuberance into the conical opening at the base of the cotyledonar tube. The cells of this mound of tissue are slightly different in size and staining properties from those around them (*fig. 13*).

The conducting tissue begins to develop as a central strand of narrow elongated cells, which extends almost to the plumule, where it divides, one division going to each of the cotyledons. The form of the mature embryo is shown by *fig. 14*, which is a diagram to represent a median longitudinal section of a mature embryo. The figure was constructed from micrometer measurements of a series of cross-sections of known thickness. This was found more satisfactory than making a drawing from a longitudinal section, because in the latter it is impossible to distinguish the place where the cotyledonar tube leaves off and the opening between the two lobes begins.

JEFFERSONIA DIPHYLLA.

The development of the embryo sac of Jeffersonia has been described by Andrews (1895). The mature embryo sac differs from the typical form only in the large size of the antipodal cells. The fecundated egg cell elongates and is divided into two cells by a transverse wall (*fig. 15*). The embryo soon elongates, the distal end becomes somewhat broadened, and a definite suspensor consisting of two or three cells is formed. The cells at the distal end are divided by longitudinal walls, but the suspensor remains as a single row of cells (*figs. 16, 17, 18*). In *fig. 18* a synergid is shown which has increased greatly in size. This is an unusual occurrence, as the synergids usually disappear early. By the time the embryo has reached the eight-celled stage a large number of endosperm nuclei can be seen scattered about in the cytoplasm of the embryo sac. The antipodal cells disappear very early.

The suspensor increases in length by the growth and division of the cells composing it. The cells divide by transverse walls until a row of four or five cells is formed. At first the body of the embryo seems to increase in size by the division of its cells in three planes, so that it becomes rounded (*fig. 19*). A little later the body elongates, and the symmetrical form shown in *fig. 20* is produced. Growth now takes place most rapidly in a lateral direction, the distal end becoming broad and truncate. *Fig. 21* represents a stage just before the beginning of the development of the cotyledons. The development of the embryo to this point corresponds very closely with that described for Podophyllum. The cavity surrounding the embryo is small, and the endosperm cells near it do not become so nearly disorganized as in Podophyllum or Caulophyllum.

Examination of longitudinal sections, or of series of cross-sections of embryos in which the cotyledons are somewhat developed, would lead one to the conclusion that Jeffersonia is a typical dicotyledon (*figs. 22, 23*). There is a slight peculiarity in the origin of the cotyledons, however, which is shown by a series of cross-sections at the stage when the cotyledonar primordium first appears. *Fig. 24* shows that the cotyledons really

have their origin as a very broad crescentic ridge of tissue. After the ridge has attained a little height it bifurcates, so that two lobes are formed.

In older stages the two lobes are of equal size and the notches are of almost equal depth. *Fig. 23* represents the condition in the mature embryo. Section *a* passes through the body of the embryo just below the growing point; *b* passes through the plumule; the remaining sections pass through the cotyledons. It will be observed that no cotyledonar tube is formed and that the edges of the cotyledons are not close together.

The mature embryo is small, both hypocotyl and cotyledons being short. The plumule has about the same development here as in the mature embryo of Podophyllum, being simply a small mound of tissue between the two cotyledons. The conducting tissue is beginning to develop as a central strand of narrow elongated cells, which divides into two branches, one going to each of the two cotyledons. *Fig. 25* shows the shape of the mature embryo in longitudinal section.

CAULOPHYLLUM THALICTROIDES.

Material for the study of the younger stages in the development of the embryo of Caulophyllum was not secured, but it is hoped that the investigation of the development of the embryo-sac and young embryo may soon be carried out.

The youngest stages examined show the embryo at about the time when the cotyledons begin to develop. The embryo at this time shows a long, slender suspensor and a rather broad, short body (*fig. 26*). From this longitudinal section the cotyledons seem to arise as two opposite ridges of about equal size, but it is impossible to say that this is the case, as cross-section series of this stage were not secured and series from embryos a little older do not support this view. A cross-section series from an embryo corresponding in size to the one represented by *fig. 27* is shown in *fig. 28*. From this figure it is apparent that the cotyledons have a common base consisting of a low ridge of tissue which bifurcates to form two very symmetrical cotyledons. Older stages show that the bifurcations soon become of almost equal

depth (*fig. 29*). The edges of the cotyledons are very close together, so that the plumule is almost inclosed in a tube. The opening just above the plumule is conical as in Podophyllum. The plumule is slightly more developed here than in Podophyllum or Jeffersonia, but consists simply of a mound of tissue. The hypocotyl is longer in relation to the size of the entire embryo than in either of these forms.

SUMMARY.

1. In each of the three plants studied the embryo is small, surrounded by a large amount of endosperm richly stored with starch.

2. In each case the cotyledonar primordium is a broad, ridge-like structure open at one side. This ridge later bifurcates opposite the opening to form two lobes, the cotyledons. The two notches soon become of almost equal depth, so that older stages do not give a correct impression of the origin of the cotyledons.

3. In Podophyllum a long cotyledonar tube is formed, and in Caulophyllum the edges of the cotyledons are close together. The plumule of Jeffersonia is not inclosed in either way.

4. The plumule is not well developed in any of these embryos, but has a central origin in each.

THEORETICAL CONSIDERATIONS.

There are among the angiosperms certain plants which show peculiarities either in their vegetative structure, their embryology, or in both. Some of these plants have flowers of very simple form, and certain botanists believe that in them we have primitive characters, and that the comparative study of a large number of these forms may reveal much concerning the origin of the structures found in more highly developed plants. Others hold that the simple forms represent merely a derived condition, and that their peculiarities are not of the highest value in determining relations, but have been acquired as an adaptation to the conditions under which the plant has developed. All agree that it is important to investigate the development of these plants, because it is only by the accumulation of a large number of facts that we have a basis for definite and reliable conclusions.

There are two points of great interest in the study of these low plant forms, when they are considered as representing primitive characters: first, the possibility of determining something concerning the origin of the angiosperms; and, second, the origin and order of derivation of the monocotyledons and dicotyledons.

The gap existing between the seed-bearing plants and the pteridophytes of the present time is wide, the nearest approach to the seed habit being found in the few heterosporous forms. It seems probable that the seed-bearing plants had their origin from heterosporous pteridophytes of past ages, and that the Gymnosperms and Angiosperms arose independently from different stocks. On the other hand, from certain similarities it seems probable that the monocotyledons and dicotyledons are derived from a common stock. If these two divisions had a common origin, the question arises as to which is the more primitive and how the other has been derived from it. There are two theories concerning this which are diametrically opposed.

The theory advanced by Lyon (1901) is that the single cotyledon is homologous with the foot of the pteridophytes, and that the dicotyledons are derived from the monocotyledons by the bifurcation of the single cotyledon as in Nelumbo. However true this theory may prove to be, it seems necessary that it should be substantiated by a larger collection of facts before it can be of great value. If the study of a large number of anomalous forms should show the ridge of tissue at the base of the cotyledons of varying height, so that a connected series could be built, it would in some measure support this theory, although even then the conditions under which the plants develop would have to be considered, as the peculiarities might represent simply derived conditions.

Opposed to this theory is that of Miss Sargant (1903) set forth in her paper on the origin of the monocotyledons. This observer argues that the monocotyledons are derived from the dicotyledons, the single cotyledon of the former having arisen by the union of the two cotyledons of the latter, and that therefore the dicotyledonous plants are the more primitive. This

theory is based on the study of the seedlings of a large number of plants, many of which show the cotyledons grown together at one or both sides.

To determine which of these theories is the more probable will require the study of the embryology and development of the seedlings of many plants in the families which show these peculiarities. Something of value may be learned by growing the seedlings under different conditions and observing results.

The interpretation of such a structure as that found in Podophyllum, or that of Nelumbo as one cotyledon or as two, must be unsatisfactory until a greater number of anomalous forms has been investigated. If the cotyledons of some of the plants which have the other characters of the dicotyledons are found to have their origin as a single ridge, it will support the view that here also we have two cotyledons and not lobes of one. The early division of the ridge in Podophyllum, as well as in Jeffersonia and Caulophyllum, leads to the conclusion that here we have two cotyledons. The fact that a cotyledonar tube is formed in Podophyllum is probably best explained as a derived condition brought about by the geophilous habit of the plant. The hypocotyl is short in comparison with the length of the entire embryo. The plumule is small and develops but little during the first year. The cotyledonar structure is long, so that, while the plumule remains underground in a protected position, the cotyledons are pushed up into the air and sunlight and carry on the work of assimilation. The great length of the cotyledons makes necessary some means of strengthening the part which must support the weight, and this is done by the formation of the tube. The fact that cotyledonar tubes have been found in families far removed from each other, and usually in embryos having a short hypocotyl, supports this view.

In Caulophyllum the ridge does not attain much height, and the later stages show that the notches are of almost equal depth and that the cotyledons are very symmetrical. The hypocotyl is long and the cotyledons short in comparison with Podophyllum. Possibly this explains why no tube is formed.

It is highly desirable to trace the development of the seed-

lings of Jeffersonia and Caulophyllum for comparison with the conditions found in Podophyllum. Up to this time (March 20) seeds of Podophyllum and Jeffersonia collected last year have refused to germinate. It seems that they require a long resting period and will not germinate until the spring following their maturity. It is hoped that this year the germination of the seeds and the development of the seedlings may be observed.

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EXPLANATION OF PLATES VII AND VIII.

PLATE VII.

FIGS. 1–14. *Podophyllum peltatum.*

FIG. 1. Section of two-celled embryo with large synergid. × 180.

FIG. 2. Eight-celled embryo. × 180.

FIGS. 3–4. Embryos with broad or rounded body and long suspensor × 180.

FIG. 5. Embryo shortly before the beginning of the development of the cotyledonar primordium. × 180.

FIG. 6. A series of cross-sections from an embryo showing the cotyledonar primordium; the sections of all the series shown in the figures are 15μ thick. × 25.

FIG. 7. A series of sections from an older embryo, showing the beginning of the cotyledonar tube, and the bifurcation of the ridge to form two cotyledons. × 25.

FIG. 8. A series of sections from an embryo in which the cotyledonar tube is somewhat developed; the bifurcations are of almost equal depth; alternate sections were drawn. × 25.

FIG. 9. Embryo of irregular shape. × 180.

FIG. 10. Longitudinal median section of an embryo at right angles to the plane of bifurcation of the cotyledonar ridge. × 100.

FIGS. 11–12. Similar to *fig. 10*, but later stages. × 100.

FIG. 13. Longitudinal section through the plumule of a mature embryo. × 180.

FIG. 14. Longitudinal section of a mature embryo of Podophyllum. × 25.

PLATE VIII.

FIGS. 15–25. *Jeffersonia diphylla.*

FIG. 15. Two-celled embryo. × 180.

FIG. 16. A later stage to show that the suspensor becomes long, before longitudinal walls are formed in the cells at the distal end. × 180.

FIG. 17. Eight-celled embryo with large synergid near it. × 180.

FIG. 18. Similar embryo with endosperm nuclei in cytoplasm of embryo sac. × 100.

FIG. 19. Older embryo in which the body is somewhat rounded. × 180.

FIG. 20. Embryo in which the body is more elongated than in *fig. 15*. × 180.

FIG. 21. Form of embryo just before the beginning of the development of the cotyledons. × 180.

FIG. 22. An embryo in which cotyledons are almost developed. × 100.

FIG. 23. A series of sections from a mature embryo.

FIG. 24. A series of cross-sections of an embryo, showing that the cotyledons begin their development as a single broad ridge. × 25.

FIG. 25. Longitudinal section of a mature embryo. × 25.

FIGS. 26–30. *Caulophyllum thalictroides.*

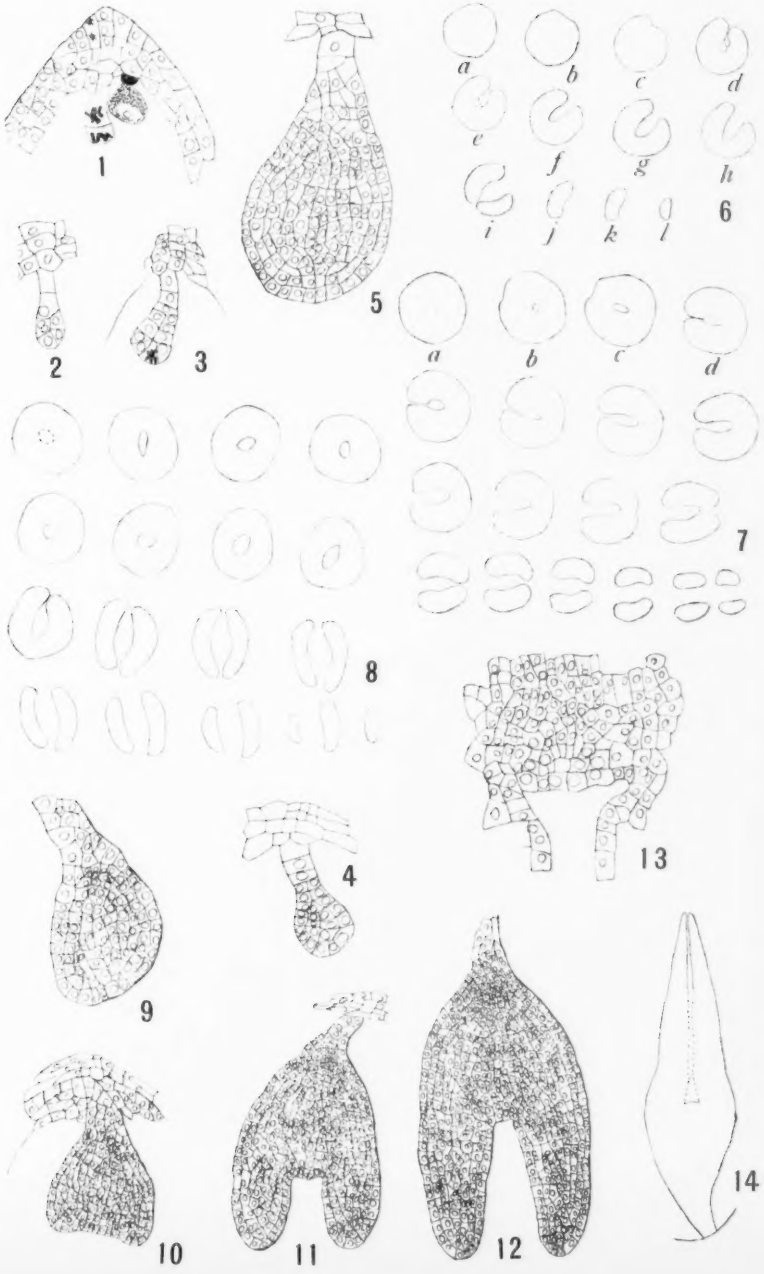
FIG. 26. Embryo at beginning of development of cotyledons. × 180.

FIG. 27. Older embryo. × 100.

FIG. 28. A series of sections through the plumule and base of the cotyledons. × 25.

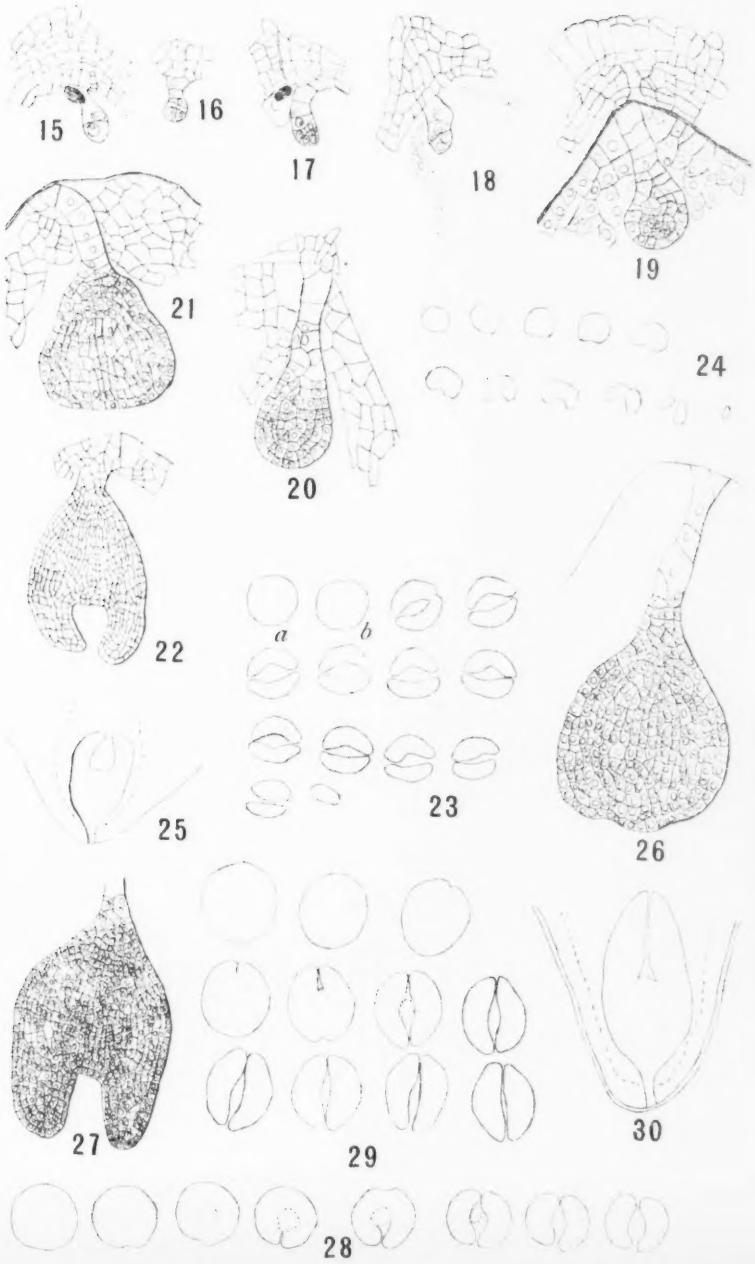
FIG. 29. A series of sections from an older embryo; the first eight sections are consecutive, the others are alternate. × 25.

FIG. 30. Longitudinal section of a mature embryo. × 25.



LEWIS, DEL.

LEWIS on EMBRYOS.



LEWIS, DEL.

LEWIS on EMBRYOS.

BRIEFER ARTICLES.

DEFORESTATION AND CREEK FLOW ABOUT MONROE, WISCONSIN.[1]

(WITH A MAP)

On a large scale and in a rather hazy way the drying up of lands whose forests are removed is a matter of history and is popularly accepted as a fact. In detail and near at hand, however, there is still some scarcity of available evidence. This note and the accompanying map show, as far as a map can, the changes in the surface flow of water which have accompanied the gradual removal of the native forest from four townships of Green county, Wisconsin.

The tract is typical of the surrounding region. To the south there is more native prairie and the forest has been more completely removed, while to the north and west a rather larger trace of the primeval forest survives. Including the neighboring towns on the east and north would not have altered the complexion of the map at all.

The land in these towns is almost wholly tillable. Underlying most of it is limestone (Galena), with a coat of clay under the fertile surface of soil; the Pecatonica River and some of the larger creeks cut through into the St. Peter sandstone. The limestone shows on the brow of a few hills and low sandstone cliffs border the valleys of the creeks in a very few places. Practically all the land can be plowed, and all of it makes valuable pasture.

The settlement of these towns began about the time of the Black Hawk War, and a number of the earliest settlers are still living. They located along the edge of the timber, and the prairie towns preceded those forested in settlement. The population increased rapidly after 1840, and by 1860 was practically what it is now. The first great use of the land was grain-growing, which has declined since the Civil War. What lumbering industry there was has disappeared with the material for it. The dairying interest has steadily grown, very rapidly during

[1] The most of the work embodied in this paper was done by Mr. Shriner and myself during the summer of 1902. After I left Monroe Mr. Shriner filled in the areas on the map where reliable information had not been obtained at the first attempt, and also prepared the map.—E. B. C.

the last twenty years, until Green is the greatest cheese-producing county in the country.

The expansion of the cheese interest made it possible for a limited rural population to get large returns from a much greater area of hilly country than it could till, and has certainly been a large cause of the final clearing of the land. At the same time the demands of the neighboring cities have advanced the price of fuel, and three lines of railroad in these four towns built during the eighties gave all parts of them a short haul to market.

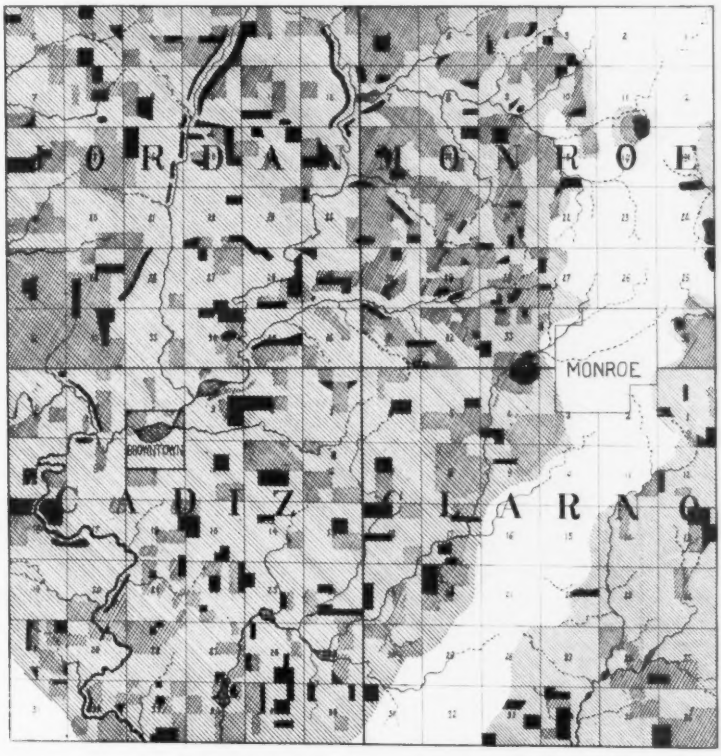
The accompanying map shows the native prairie and forest, the timber removed during the last fifteen or twenty years and that standing now, the water courses and former water courses now dry a large part of the year, and most of the former millponds. I have determined, by weighing them, the relative areas differentiated on the map, the result being: prairie 16.8 per cent., original forest 83.2 per cent., cleared fifteen to twenty years ago 55.9 per cent., cleared within fifteen to twenty years 27.3 per cent., timbered now (September 1902) 5.8 per cent.

"Fifteen to twenty years ago" is inexact, but it is usually impossible to tell exactly when a given tract was cleared, and any sharp line is therefore impracticable. The time indicated is that at which we became personally familiar with the country. It is also difficult, when the trees are gradually cut from an area, saw-logs first, cordwood a decade later, the young trees later still, or when some more or less abundant kinds are spared in the cutting, to decide when it ceases to be fitly mapped as timber. We have called any land timbered as long as the heavy shade is more continuous than the sod — a loose test, but as good as we knew.

The map and the figures based on it cannot show the change in the character of what timber remains. The forest was never homogeneous, but in general it was as dense as temperate deciduous forests often are. In general there was a considerable mesophytic undergrowth of thin leaved shrubs and herbs; more rarely the forest was dense enough to keep its floor relatively clear. In either case the ground was kept open and loose and the air over it cool and moist. In these four towns not a ten-acre grove of such forest is left. The surviving timber is pastured and the ground is tramped. The shade-loving, shade-making mesophytes disappear and grass gradually comes in. The trees become less vigorous and the grass more so. No axe is now needed. The grass-covered ground with scant shade is harder and smoother than the old forest soil, and dries very much more rapidly.

The vanishing percentum of surviving forest is thus practically even less than it appears.

From the settlement of the country until at least 1887 practically no creeks went dry, though there was a noticeable lowering. Since that time, according to the map, the water courses that are dry during



MAP OF PART OF GREEN COUNTY, WIS.

the entire summers or longer amount to 29½ miles in Monroe, 10¾ miles in Jordon, 7½ miles in Cadiz, and 17¾ miles in Clarno, a total

of 65½ miles. This falls short of the real fact, because in Jordon and Cadiz, in the absence of certainty about some former creeks, we have omitted them; and because in exceedingly dry times the water has disappeared further than we represent, and these are the crucila times.

With the drying up of their head waters, the flow of the creeks has of course diminished everywhere. There are no measurements of flow at any time in the past, and, having nothing to compare with, we have made none. The millponds show the state of affairs most graphically. Rich, Honey, and Skinner Creeks each ran several mills; altogether there were twelve of these. All have been discontinued or equipped with steam power. On each creek there were running by water power twenty years ago at least two mills. The occasion for saw and grist mills is largely gone—reason enough why some of them are absent; but several now use steam. One mill near the mouth of Skinner Creek uses both water and steam. Where most of these mills stood less water runs now than used to be wasted.

A change in the forest covering of a region might indirectly affect the stream flow, through an effect on the total rainfall or its seasonal distribution; we have no evidence that this occurs. And the more direct effect in changing the structure and exposure of the ground might be years in making itself fully seen. Still, because of the length of the time involved, and because the deforestation had been relatively slow for some time preceding twenty years ago, we conclude that the creek flow there was adjusted to the forest area and condition; likewise, there having been no considerable change within five years, the timber and creeks seem to be in equilibrium now. If this be so, and assuming still that these four towns fairly represent the general region near about them, we can conclude that 27 per cent. of forest will nearly enough conserve the surface flow of water in country originally 83 per cent. forest so that the difference does not appear in any considerable loss of springs or drying up of creeks; but that if this forest be further reduced to 6 per cent., many creeks dry up and the flow of water in those remaining is reduced to probably about one-third.

About the rainfall in Monroe nothing exact is known, and if we had data, their relation to the deforestation would be very doubtful. While the loss of flowing water is a very local function of deforestation, the rainfall, if it be a clear function, is not localized at all. And the variation in different seasons and localities is so great that very extensive data in space and in years, as to both rainfall and the timbered

area, would be needed to make conclusions of any value. From the Weather Bureau reports at our disposal from stations from Milwaukee to Dubuque, some of them going back to 1871, it does not appear that there has been any significant change. The last decade includes dry years and wet years, dry and wet summers.

The influence of deforestation on the character of the flora is another interesting subject. While the relative representation of different components of the flora has of course changed profoundly, remarkably few plants have as yet become extinct. No tree has certainly disappeared except the juniper, which had a single locality and has not been seen within thirty years. We have the only local herbaria of any size, that of Herbert E. Copeland dating from the early seventies, and our own, mostly about seventeen years later. The only plants whose disappearance in that interval is highly probable are *Camassia Fraseri* and *Pogonia pendula*. In the last fifteen years *Cypripedium spectabile*, *Gaultheria procumbens*, *Phegopteris Dryopteris*, and possibly as many more plants all strictly local, seem to have been killed out. On rare rough hillsides and in gulches where the timber is relatively native, and in fence corners, in brush, or around stumps, the old flora persists. It is a most instructive lesson in the survival of what exists that above thirteen-fourteenths of the native habitat has been altogether changed in character, and the other one fourteenth decidedly modified, without the extinction of a single common forest herb, shrub, or tree.—F. A. Shriner and E. B. Copeland, *Monroe, Wis.*

THE EFFECTS OF EXTERNAL AGENTS ON THE PRODUCTION OF ROOT HAIRS.

PRELIMINARY NOTICE.

During an endeavor to find the causes for the production of root hairs, results were obtained, which, though incomplete, may be of sufficient interest to warrant publication.

Seedlings of *Zea mais*, *Helianthus annuus*, *Lupinus albus*, *Avena sativa*, *Triticum vulgare*, *Vicia sativa*, *Cucurbita Pepo*, *Raphanus sativus*, *Brassica alba*, and *Cannabis sativa*, grown in water, showed a tendency not to develop typical water roots at once, but produced a longer or shorter zone of hairs, passing, in some forms, into the smooth surface usually characteristic of water roots. Apparently this zone of hairs in sunflower, radish, and white mustard was not directly influenced by light or darkness.

In solutions seedlings showed a general tendency for the hair development to vary with root development, though the results are rather discordant, and more work is required before any conclusion can be reached. The roots seem to be able to bear higher percentages of saccharose than of lactose, glucose, glycerin, mannite, or modified Knop's solution, a result in accordance with that of Livingston. The discordance of results above mentioned may be due, in part at least, to the absorption of different chemicals from the different kinds of glass in the vessels used, since Benecke found such absorption to influence the development of rhizoids in Lunularia.

The effect of the quantity of food is of importance, apparently, because of its influence upon the growth of the root. Seedlings of Helianthus, whose cotyledons had been cut off at various distances from their insertion, produced different root lengths corresponding to the lengths of cotyledons remaining, and the hair development varied accordingly.

The oxygen pressure in water was varied by boiling, with no very marked difference in the hair production of corn seedlings. Further experiments in variation of oxygen pressure are in progress.

From the cases mentioned there appears to be a tendency for seedlings under most conditions to produce a longer or shorter zone of hairs, probably on account of the surplus energy provided by the stored food.

The growth of roots is more rapid in water than in air of the same temperature (as has frequently been noted), with hair production in inverse relation; the water condition appears to be produced, however, in saturated air. The average length of epidermal cells in water roots exceeds that of the same cells in air roots, though the average number of cells produced each day appears to be approximately the same under the same conditions. Therefore the increased length, in this case at least, seems to be due to greater elongation of the cells of the water roots. In the same section there appears in general to be a relation between the length of the cells and the production of hairs, the average length of hairless cells being greater than that of cells with hairs.

A retardation of growth when the root tip meets with resistance causes the root to kink and produce hairs. If wounded, the growth is also retarded, and the region immediately behind the tip usually becomes abnormally enlarged, and at the same time shows a marked tendency to form hairs.

In accordance with the statements of Haberlandt and Schwartz, Elodea roots, though hairless in water, produce hairs when growing in the substratum of the aquarium, even if the material be ground quartz. Microscopic examination has shown thus far that the average length of epidermal cells of roots in the substratum is less than that of epidermal cells of roots in the water. The presence of hairs seems to be related, therefore, to the length of the cells rather than to superficial contact. In support of the idea that contact of the epidermal cells with solid bodies does not appear to be a stimulus for hair production, may be cited certain instances where roots of seedlings grew against the sides of a glass vessel; in this condition there was a marked tendency for the suppression of hairs along the region of contact. Also seedlings grown in saturated sand or garden soil show a diminution or even absence of hairs, as previously indicated by Persecke.

That temperature has an effect, though possibly an indirect one, upon hair production is evidenced by roots of corn and wheat seedlings showing a tendency to omit the hair zone when growing rapidly in warm water.

From the foregoing statements there appears to be a relation between the production of root hairs and the elongation of the cell; whatever has a tendency to increase the elongation also tends to suppress the development of hairs, "water etiolation" being especially important in this connection in soil roots. In two cases of decapitated sunflower seedlings the water etiolation of the periblem and epidermis was apparently so great that the poorly nourished, deeper lying plerome was not able to keep pace with it and hence split transversely in several places. The frequently noted decrease of hairs in etiolated conditions of the aerial parts of plants, whether from darkness or moisture, supports this view.

The production of hairs coincident with slow growth above mentioned is not thought to be due to excess of nourishment, as supposed, but merely to the tendency of the cells to grow transversely rather than to elongate longitudinally. This is supported by the condition of affairs in Lycopodium and Isoetes, and by Leavitt's association of root hairs of Azolla with cells which do not elongate. The root hair problem therefore, appears, to resolve itself in large part into the search for the causes of arrested growth or the elongation of cells.

Other references, illustrations, and conclusions will be reserved until the work is more complete. — LAETITIA M. SNOW, *Hull Botanical Laboratory, The University of Chicago.*

PRESERVATION OF SEEDS BURIED IN THE SOIL.

DURING the latter part of the winter of 1901–2, while the new medical building was being erected on the campus at the University of of Michigan, an excavation was made adjacent for the purpose of securing gravel and sand to be used in the masonry work. At this particular time I happened to be reviewing the literature pertaining to the vitality of buried seeds, and was thus prompted to see what this pit would yield. An investigation revealed a layer of black soil, approximately one inch in thickness, at a depth varying from fourteen to sixteen inches below the surface.

On March 7, 1902, while the ground was frozen very hard, samples of this black soil were taken from three different places, representing in all approximately two square feet of surface. This soil was then distributed in four eight-inch clay pans, which were placed in the greenhouse under favorable conditions for the germination of any seeds that were lying dormant in the soil. The pans were covered with glass plates so that no foreign seed could enter during the course of the experiment.

On March 14 pan no. 1 showed four clovers; pan no. 2 six clovers and four plantains; pan no. 3 twelve clovers and two plantains, and pan no. 4 thirteen clovers and two plantains; a total of thirty-five clovers and eight plantains in seven days. New seedlings continued to appear from day to day. The experiment was terminated on May 6, after a period of sixty days, when the entire number of seedlings had reached 128, representing seven genera and nine species, as follows: *Trifolium pratense* L., 70; *Polygonum aviculare* L., 19; *Plantago Rugelii* Dec., 10; *Euphorbia maculata* L., 8; *Panicum pubescens* Lam., 6; *Plantago major* L., 5; *Bursa bursa-pastoris* (L.) Britton, 5; *Trifolium repens* L., 3; *Anthemis Cotula* L., 2.

On inquiry it was found that the grading in that part of the campus was done in the autumn of 1898, consequently the seeds giving rise to these plants must have been lying dormant in the soil at least three and a half years.

In addition to the species named above, an examination of the soil showed the presence of many old fruits of *Ambrosia artemisiaefolia* L., but the vitality of these had been destroyed.

The conditions in this particular place were very favorable for the preservation of vitality of buried seeds. The first six or seven inches below the new surface consisted of a firm clay, below which was a mix-

ture of clay and gravel. Directly underneath the stratum of the original surface soil which contained the seeds was a very thin layer of clay, below which was the bed of gravel and sand.

These seeds were not buried sufficiently deep to prevent them from being frozen, but the layer of clay above served quite well to protect them from the air, thus diminishing the respiratory activity, and the gravel and sand beneath furnished the best possible conditions of drainage. Under such favorable conditions the vitality of many seeds might be preserved, when buried in the soil, for a score of years or more.—J. W. T. DUVEL, *U. S. Department of Agriculture, Washington, D. C.*

CUMAPHYTISM IN ALARIA.

(WITH TWO FIGURES)

AMONG the species of Alaria displayed upon the kelp beds of the Minnesota Seaside Station, the one named *Alaria nana* by Mr. H. F. Schrader[2] has been found to show a somewhat remarkable adaptation to the surf habitat which it shares with *Postelsia palmaeformis* Rupr. along the Straits of Fuca. Plants of *Alaria nana* are found intermingled with Postelsia and form for the most part an undergrowth between the trunks of the larger kelp. Upon few rocks have there been found unmixed growths of Alaria. Last summer, however, I was enabled to examine two or three beds of *Alaria nana* which had not come under the observation of Mr. Schrader. A series of plants was collected for the laboratory work in the University of Minnesota, and two of them have been photographed to accompany these notes. Their consideration will make it apparent how strongly the Alaria type may become adapted to existence in the surf.

When growing intermixed with Postelsia the common form of *Alaria nana* is as shown in *fig. 1*. The plants will not average more than 20^{cm} in length. In these plants the mid-lamina is well developed, and the gonidiophylls are comparatively slender and their entire surface, with the exception of a narrow marginal region, is soral. Toward the base of a Postelsia formation the plants of *Alaria nana* average somewhat larger, and the stipes are not erect, but decline upon the rocks. Higher in the formation the size of the plants diminishes and the stipes become more erect, until well toward the top the erect habit

[2] SCHRADER: Observations on *Alaria nana*, sp. nov. Minn. Bot. Studies 3: 157. 1903.

is the rule. At the same time the stipes become more massive and the gonidiophylls become broader.

Along the top of the formation, at two or three localities, decidedly unusual plants of *Alaria nana* have been observed. Sometimes hundreds of these are found growing together. *Fig. 2* shows such a plant placed upon the right of and beside an individual of *Postelsia palmaeformis* which is introduced for comparison. The plant shown in *fig. 2* is but 10^{cm} in height, nor do plants of this form ordinarily measure much more than this. The general resemblance in habit to Postelsia

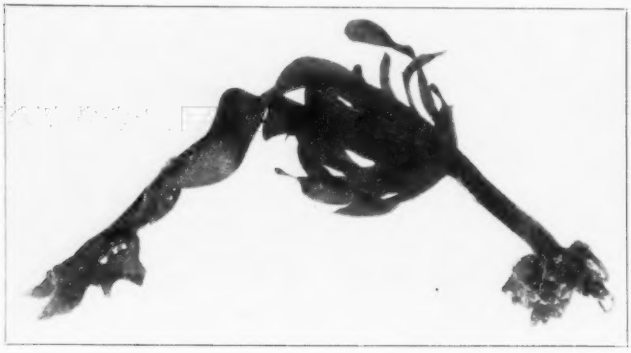


FIG. 1.—Plant of *Alaria nana* H. F. Schrader; natural size about 20^{cm} in length. After photograph by C. J. Hibbard.

is certainly very marked. The mid-lamina is in all such plants eroded to the base or but poorly developed. Under such conditions it is evident that the gonidiophylls must assume the photosynthetic function, and they have consequently taken a broader form. One of these obovate gonidiophylls is clearly shown in the figure. Upon many of these gonidiophylls soral areas are either not developed or limited to the basal portion. The number, too, of the gonidiophylls seems to be increased as compared with normal plants of the lower levels. The stipe is quite erect, very firm, and provided with a strong growth of hapteres at the base. In general, the plant which has come to live under the conditions to which Postelsia has adapted itself receives the imprint of environmental forces, as did the ancestral forms of the other kelp, and exhibits a striking homoplasy.

In comparing the plants shown in *fig. 2*, it should be remembered that Postelsia, a member of the Lessonia group, is essentially unilami-

nate, and the laminae displayed at the summit of the stipe have arisen by repeated longitudinal splitting of the original single lamina. Alaria, on the other hand, maintains its original mid-lamina without splitting, and this would be found at the center of the tuft, while the conspicuous laminae are the modified and hypertrophic gonidiophylls.

FIG. 2.—Plants of *Postelsia palmaeformis* Rupr. (on the left) and *Alaria nana* H. F. Schrader (on the right). Extreme cumaphytic form. After photograph by C. J. Hibbard.

Yet, while developed in this different manner, the ultimate result is, in each case, a tuft of leaves at the end of a short, thick, and firmly attached stipe.

The series of plants as displayed upon the rocks is certainly very instructive and to be fully appreciated must be studied in the field. In this note I have attempted merely to indicate the extreme form which an Alaria may assume in the cumaphytic habitat.—CONWAY MACMILLAN, *University of Minnesota.*

CURRENT LITERATURE.

BOOK REVIEWS.

European moss flora.

THE SECTION of the monumental *Kryptogamen-Flora von Deutschland, Oesterreich, und der Schweiz* which describes the mosses, *Die Laubmoose* by Limpricht, has not yet quite come to completion, and the lamentable death of its author will doubtless delay somewhat the issue of the last supplementary parts. It has been in course of publication since 1886. This for central Europe, with the recent descriptive works on the mosses of France and England, have been the only dependence of bryologists who wished anything more recent than the second edition of Schimper's *Synopsis Muscorum* (1876). But no general work later than the latter touches Spain, Italy, Russia, or the Scandinavian countries. It is high time, therefore, for such a gathering together of the data on the species of mosses and their European distribution as seems planned in *Die europäischen Laubmoose*[1] by the grand-ducal "Rechnungsrat" at Laubach (Hesse), Georg Roth. The publication begins without preface and with the briefest prospectus. Evidently, from the quickness with which part follows part, the manuscript is ready for the publisher and the work, in ten or twelve parts, making two volumes, is not to drag its weary length along, as some of its predecessors have done. The parts (not sold singly) consist of 128 pages each, with ten plates, and are issued at the remarkably low price of 4 marks. The plates are photolithographs, very crowded and of rather inferior quality, though whether this inferiority is due to the drawing, which is done by the author, or to the process of reproduction is uncertain. Nevertheless, plates are quite indispensable in such a work and these are certain to be helpful, especially in showing those differential characters which can be only imperfectly conveyed by words.

The systematic arrangement departs very little from that of Schimper's *Synopsis* and Limpricht's *Laubmoose*, so as to reduce to a minimum the difficulties of using the books together.

In an introductory section of 100 pages the general characteristics, anatomical structure, reproduction, geographic distribution, and ecology of the mosses are treated, followed by brief directions for collecting and naming, and illustrated by three plates. This section, necessarily quite elementary, is well done, especially the chapter on ecology.

The descriptions are in German, covering half a page to a page, with diagnostic characters indicated. The synonymy is brief, and the habitat and distributions are given rather fully. The Sphagnaceae will be excluded.

[1] ROTH, GEORG, Die europäischen Laubmoose. Imp. 8vo. Parts 1–4. pp. 1–572. *pls. 1–36, 46–49.* Leipzig: Wilhelm Engelmann. 1903. *M* 4 per part.

The work bids fair to be a most satisfactory one. A similar work for North America is greatly to be desired, for Lesquereux and James's *Mosses of North America* is now twenty years old.—C. R. B.

The problems of life.

THIS BOOK[2] contains a theory of ontogenic development, or rather an exposition of the fundamental principle governing ontogenic phenomena. To use an illustration of the author: if one wished to study the flow of rivers, and to determine in advance the course of a river in all its details, it would be necessary to know the rapidity and density of the water, the inclination and geological structure of the bed and banks at all points of its course, resistance of materials composing these, etc., so that the solution becomes practically impossible in detail. But theoretically the fundamental principle involved is simply that of gravitation. It is the same with the problem of development. Knowledge of all the various secondary factors that complicate each case is not necessary; what is wanted is knowledge of the fundamental principle governing all ontogenic phenomena. The author believes he has found this in the principle of "développement monodique."

The principle of monodic development is derived from the author's ideas of the nature of assimilation, growth, and of cell division, which are discussed in the first part of the work, and are outlined in a review of it in this journal.[3]

The biomolecules of the egg assimilate the deutoplasm and so reproduce by division; this causes division of the biomores, and this cleavage (cell division). Thus assimilation is the first and necessary cause of each cleavage, and the assimilation is accompanied by progressive chemical ontogenic changes. The author here introduces as the main prop of the monodic theory the principle of "heterogenetic" development, viz.: that, owing to the nature of "biomolecular development," two daughter-cells must be different in constitution both from one another and also from the mother-cell. This is established as a universal principle in development by the consideration that there are only two other possible modes of cell division, viz.: *autogenetic*, in which the daughter-cells are like each other and also like the mother-cell, and *homogenetic*, in which the daughter-cells are like each other but different from the mother-cell, and that these are excluded as possible modes of development, for the assumption of either of them as a mode of development leads to an absurdity.

Thus it follows that the constitution of the cells alters with each cleavage which *ex hyp.* is preceded by a period of assimilation. .

The next step in the hypothesis leads to the principle of monodic develop-

[2] GIGLIO-TOS, ERMANO, Les problèmes de la vie. II^e^ partie; l'ontogénèse et ses problèmes. 8vo. pp. 368. Cagliari, chez l'Auteur, à l'Université, 1903.

[3] BOT. GAZ. 31:275. 1901.

ment. Supposing that the bioplasm of the egg passes through stages *a*, *b*, *c*, owing to the nature of the processes of assimilation of the biomolecules, biomores, etc., it is clear, the author states, that the first division of the egg cell *a* must result in two cells, one of which, on the principle of heterogenetic development, must be *b* and the other different from *b*; it may be *c* or it may be something different. "There are no other possible suppositions." The author examines the second alternative, "polyodic development," first, and arrives at the conclusion that this leads to an absurdity; hence the egg *a* must divide into *b* and *c*; *b* must divide into *c* and *d*; *c* into *d* and *e*, and so on to a particular limit fixed by the constitution of the egg. This is the principle of monodic development.

It would take us too long to follow the author's exposition of how this principle leads to a "rational" explanation of the development of all animals and plants, leaving no essential phenomena unexplained; and, moreover, it is not necessary to do so for already two things must be clear: (1) that the author has reared an inverted pyramid upon his conception of assimilation and growth; (2) that by the naïve method of proposing selected theoretical alternatives and demonstrating the absurdity of all but one, any principle may be "proved," the premises being granted.

Some of the main features of this system remind one of certain theories of Weismann, *e. g.*, the theory that protoplasm is a symbiotic aggregation of various orders of living units. But Weismann is far too good a biologist to endow the molecules themselves with life. The principle of "heterogenetic development" has some points of resemblance to the principle of "qualitative nuclear division" (Weismann). But the system of Giglio-Tos is more artificial than that of Weismann, and he tries to solve by force of *a priori* reasoning what Weismann is careful to consider on the evidence. In many respects the theory departs widely from Weismann's.

The book contains no new facts, though the author is evidently familiar with some of the current embryological literature; but he makes use of the knowledge only to show that his theory is capable of explaining all of the results of experimental embryology. With other results of recent embryological work he is apparently quite unfamiliar. Thus he declares positively in favor of the doctrine of isotropy of the egg, without the least consideration of all the many facts demonstrating that the organization of the egg is causally related to some of the most fundamental phenomena of development.

It is a Rip van Winkle experience to read this production; one wonders if all the results of exact and experimental embryology are only a pleasant dream, and if such attempts to explain inheritance by a single principle, characteristic of the biology of twenty or thirty years ago, are alone real. Fortunately even this book cannot bring one to such a conviction, and it is even probable that it will not be considered superfluous in the future to work for the discovery of new facts in ontogeny.—FRANK R. LILLIE.

The honeysuckles.

THE FOURTEENTH ANNUAL REPORT of the Missouri Botanical Garden, covering the year 1903, fully maintains the high standard of scientific excellence which has characterized this series of papers from the start. The report of the director contains much of interest in regard to the growth and usefulness of the various collections, their increase for some years past being graphically shown by a series of diagrams.

The body of the report is devoted to a systematic treatment of the genus Lonicera by Mr. Alfred Rehder, of the Arnold Arboretum of Harvard University. Although published under the modest title of a synopsis, this important paper is in reality a detailed monograph. It is true that specific descriptions, except in the case of newly characterized species, have been omitted in order to keep the paper within the limits of convenient publication, but the unusually full keys present so completely the differential features that the lack of further descriptions will scarcely be felt. Mr. Rehder began his work on the genus at the Botanic Garden of the University of Göttingen and completed it at the Arnold Arboretum. During its progress he has been able to visit a great number of the larger herbaria, both of Europe and America, and to see living in the wild and under cultivation more than a third of the species of Lonicera. Without tending to a minute division, he recognizes as valid 154 species and subdivides many of them into more or less clearly marked varieties and forms. The citation of bibliography, synonymy, icones, exsiccatae, and ranges is marvelously detailed. The genus is divided into two subgenera, CHAMAECERASUS (including 131 species) with 2-flowered mostly pedunculate cymes and distinct leaves, and PERICLYMENUM (including 23 species) with 3-flowered sessile cymes, the upper leaves being usually connate. The first subgenus is again divided into four sections, namely, *Isoxylosteum* Rehder with regular corollas; *Isika* DC. with labiate corollas, connate usually red fruit, and solid branches; *Coeloxylosteum* Rehder with labiate corollas, connate usually red fruit, and fistulose branches; and *Nintooa* DC. with labiate corollas and distinct usually black fruit. These sections are again subdivided into many subsections, mostly of the author's own delimitation. Of the twenty American species recognized, only seven belong to the first great subgenus Chamaecerasus, and these are all of the section Isika, the remaining thirteen North American and Mexican species being of the subgenus Periclymenum. The author makes some thirteen new species (and specific combinations) chiefly of Asiatic plants, and also recognizes some thirty-five new varieties and forms. So far as America is concerned, the novelties are chiefly Mexican. Little change is made in the naming and specific delimitation of our North American species. Due attention has been given to the numerous artificial hybrids, horticultural species, and forms of unknown habitat — the bane of the systematist. Mr. Rehder's paper is truly noteworthy, not only for its sound scholarship, but for the equal personal familiarity with the plants of the two continents; indeed, it is prob-

ably the most detailed treatment ever published in America of a large and difficult genus chiefly of Old World distribution. The paper is well illustrated both from drawings by the author and photographic reproductions.

The closing pages of the report are occupied with an extensive supplement to the Catalogue of the Sturtevant Prelinnaean Library, compiled by Mr. C. E. Hutchings, and including several hundred titles.—B. L. ROBINSON.

MINOR NOTICES.

THE CURRENT NUMBER of the *Minnesota Botanical Studies* (Ser. III, part II, pp. 209–273) contains the following papers: "The moss flora of the upper Minnesota River," by JOHN M. HOLZINGER, being a report of material collected under the auspices of the Minnesota Botanical Survey during the summer of 1901, and including 96 numbers, 6 of which are new species; "Two new species of Fontinalis," by J. CARDOT; "Outline of the history of leguminous root nodules and rhizobia with titles of literature concerning the fixation of free nitrogen by plants. III," by ALBERT SCHNEIDER; "Report on two collections of Hepaticae from northwestern Minnesota," by A. W. EVANS, including 32 numbers; "Observations on the tide pool vegetation of Port Renfrew," by S. A. SKINNER, in which, aside from the distribution of species, the conclusions reached were that the higher the elevation of the pool and the less exposed to wave action, the fewer the species found, though individuals may be abundant; the more gradual the slope and the rougher and more irregular the sides, the more abundant the plant life; and the presence of pebbles and loose rocks on the bottom of a pool prevent the distribution of plants over the bottom or far down the sides of the pool; "Observations on *Alaria nana*, sp. nov.," by H. F. SCHRADER; "Contributions to a knowledge of the lichens of Minnesota. VIII. Lichens of the northern boundary," by BRUCE FINK, being a study of lichen formations, together with a list of 310 species and varieties with their stations; "The Umbellales of Minnesota," by W. A. WHEELER, showing 5 Araliaceae, 33 Umbelliferae, and 9 Cornaceae; "The Pteridophytes of Minnesota," by HAROLD L. LYON, containing 74 numbers; "An addition to the knowledge of the flora of southeastern Minnesota," by C. O. ROSENDAHL, being an extension of the work of the Botanical Survey, resulting in the addition of nearly 100 species to the state list; "A new species of Razoumofskya," by C. O. ROSENDAHL.—J. M. C.

OTTO KUNTZE has revised Tom von Post's *Lexicon Generum Phanerogamarum*,[4] a work that has demanded a tremendous amount of drudgery, but which should be of corresponding service to taxonomists. Included in the volume is Dr. Kuntze's *Codex brevis maturus* of botanical nomenclature

[4] POST, TOM VON, Lexicon generum phanerogamarum inde ab anno MDCCXXXVII cum nomenclatura legitima internationali et systemate inter recentia medio. Opus revisum et auctum ab OTTO KUNTZE. Stuttgart: Deutsche Verlags-Anstalt. 1904. *M* 10.

(40 pp.), printed in German, French, and English. Then follows the alphabetical list of approved genera (612 pp.) with their synonyms, fossil genera, and such cryptogamic generic names as needed change being included. A closing part (100 pp.) gives the list of valid genera under their families, which may serve also for herbarium arrangement. For twenty years Dr. Kuntze has been working at nomenclature, always confident of his ground, never discouraged by opposition or indifference, as ready now to force his views upon botanists as ever. His general attitude is indicated in the following quotation from the preface: "May our lexicon reestablish international order in nomenclature and reasonable harmony between botanists! There seems no other remedy." The present publication certainly contains a mass of information conveniently arranged.—J. M. C.

In a paper on Tertiary plants, D. P. Penhallow[5] has recorded the results of his studies of a collection of fossil woods secured by Dr. G. M. Dawson during the British N. Am. Boundary Survey. The determinations are based upon stem structure, and include new species of Sequoia, Cupressoxylon, and Rhamnacinium. A section of the paper entitled "biological considerations" discusses spiral tracheids, uniseriate rays, resin cells and passages, ray tracheids, and fusiform rays. The interesting statements are made that the occurrence of resin passages in Abies has not been traced beyond existing species, and that in reference to certain characters Sequoia represents a transitional group and also the terminal member of a short side line which passes through Taxodium.—J. M. C.

The eighteenth part of Engler's *Das Pflanzenreich* includes a presentation of Taxaceae by R. Pilger.[6] The usual full and critical discussion of the group involves in this case many mooted points of great interest to the morphologist. In addition to the eight genera that ordinarily appear under Taxaceae the author recognizes two others: *Pherosphaera* Archer, a genus of 1850 that includes two species usually referred to Microcachrys and Dacrydium; and *Acmopyle* Pilger, nov. gen., a New Caledonian genus established to include a species variously referred to Podocarpus and Dacrydium. —J. M. C.

The third part of Sargent's *Trees and shrubs*[7] contains plates and descriptive text of species of Magnolia, Liriodendron, Crataegus (8, 6 n.spp.), Tilia, Euonymus (4, 1 n.sp.), Acer (2), Virburnum (n.sp.), Lonicera (2), Ligus-

[5] Penhallow, D. P., Notes on Tertiary plants. Trans. Roy. Soc. Canada II. 9: 33–95. 1903.

[6] Engler, A., Das Pflanzenreich. Heft 18. Taxaceae von R. Pilger. pp. 124. Leipzig: Wilhelm Engelmann. 1903. *M* 6.20.

[7] Sargent, Charles Sprague, Trees and shrubs. Illustrations of new or little known ligneous plants prepared chiefly from material at the Arnold Arboretum of Harvard University. Part III. pp. 101–150. *pls. 51–75*. Boston and New York: Houghton, Mifflin & Company. 1903.

trum (2), Gryphocarpa (new genus of Compositae from Mexico), Vaccinium, and Pinus (n.sp. from W. Indies).—J. M. C.

CH.-ED. MARTIN[8] has described with great fulness the exceedingly variable fungus called *Boletus subtomentosus* as displayed in the region about Geneva. After a presentation of the bibliography and a discussion of the general characters, he describes eleven subspecies and illustrates them with 18 colored plates.—J. M. C.

WITTROCK[9] has published a very interesting set of photographs of botanists in the collection at the botanical garden at Stockholm, accompanying them with biographical notes. The plates contain the reproduction of 213 photographs, some of them representing well-known botanists at different ages.—J. M. C.

PART 217 of Engler and Prantl's *Die natürlichen Pflanzenfamilien* contains the Lichens (*Flechten*), by A. Zahlbruckner. Part 218 contains the Schistostegaceae, Drepanophyllaceae, Mitteniaceae, and Bryaceae, by V. F. Brotherus.—J. M. C.

THE SIXTH PART of John Donnell Smith's enumeration of Central American plants[10] has been distributed. It comprises a list occupying 87 pages, and three separates containing descriptions and plates of new species. —J. M. C.

THE CURRENT FASCICLE of Richter's *Plantae Europaeae*[11] concludes the Caryophyllaceae and continues the list to Clematis among the Ranunculaceae, the sequence being that of Engler.—J. M. C.

NOTES FOR STUDENTS.

ASO finds[12] that the best value of the ratio CaO : MgO for the mulberry lies between 2 and 3, an excess of magnesia over lime dwarfing plants very much.—C. R. B.

[8] MARTIN, CH.-ED., Le "Boletus subtomentosus" de la région génevoise. Matériaux pour la flore cryptogamique suisse **2**: fasc. 1. 1903.

[9] WITTROCK, V. B., Catalogus illustratus iconothecae botanicae horti Bergiani Stockholmiensis anno 1903; notulis biographicis adjectis. Acta Hort. Berg. **3**: no. 2. pp. 198. *pls. 46*. 1903.

[10] SMITH, JOHN DONNELL, Enumeratio plantarum Guatemalensium necnon Salvadorensium Hondurensium Nicaraguensium Costaricensium. Pars VI. Baltimore, Md.: The author. 1903.

[11] GÜRKE, M., Plantae Europaeae. Enumeratio systematica et synonymica plantarum phanerogamicarum in Europa sponte crescentium vel mere inquilinarum. Operis a DR. K. RICHTER incepti. Tomus II, fasc. 3, pp. 321–480. Leipzig: Wilhelm Engelmann. 1903. *M* 5.

[12] ASO, K., On the influence of a certain ratio between lime and magnesia on the growth of the mulberry tree. Bull. Agric. Coll. Tokyo Imp. Univ. **5**: 495–499. *pl. 27*. 1903.

WITMER STONE[13] has published the results of his study of racial variation among the violets, and in connection with a general discussion of the subject has published a synopsis of the violets of Philadelphia and vicinity. —J. M. C.

L. M. UNDERWOOD[14] has published synopses of the genera of ferns known to exist in the Philippines, and states that the fern flora of these islands as known today embraces over 600 species, and that probably exploration will yield half as many more.—J. M. C.

TSCHIRCH with the assistance of Herr Gerdts, has examined the anthers of a number of Compositae and finds that their union (about which statements vary from coalescence to mere adhesion) is dependent wholly upon the cuticle of adjoining anthers, which is adherent, often freeing itself completely from the epidermis that produced it.[15]—C. R. B.

P. GUÉRIN[16] has called attention to the strong development of antipodal tissue in certain species of Gentiana. This expresses itself in the increased number and size of the cells; and in the extreme case, as in *G. campestris*, the antipodals form a layer of tissue almost completely lining the embryo sac. Such tissue is resorbed upon the formation of endosperm.—J. M. C.

ASO adduces[17] objections to the view of Kastle and Loevenhart[18] that oxidases are merely "peroxids formed when autoxidizable substances come in contact with air, and these peroxids give up a part of their oxygen to other less oxidizable substances present in the cell." He also has discovered in plants traces of nitrites, which seem to be formed by oxidation of ammonium salts.—C. R. B.

MR. and MRS. WEEVERS find that caffein, which has already been shown by Clautriau and by Suzuki to be probably a decomposition product of proteids, is not a waste product, but can be utilized in metabolism, as indicated by its gradual disappearance from young parts as they develop. From tea leaves caffein disappears only as the leaves become aged and yellowed before falling.[19]—C. R. B.

[13] STONE, WITMER, Racial variation in plants and animals, with special reference to the violets of Philadelphia and vicinity. Proc. Phil. Acad. **1903**: 656–699.

[14] UNDERWOOD, L. M., A summary of our present knowledge of the ferns of the Philippines. Bull. Torr. Bot. Club **30**: 665–684. 1903.

[15] TSCHIRCH, A., Sind die Antheren der Kompositen verwachsen oder verklebt? Flora **93**: 51–55. *pl. 2.* 1904.

[16] GUÉRIN, P., Sur le sac embryonnaire et en particulier sur les antipodes des gentianes. Jour. Botanique **17**: 101–108. *fig. 9.* 1903.

[17] ASO, K., On the chemical nature of oxidases. Bull. Agric. Coll. Tokyo Imp. Univ. **5**: 481–489. 1903.

[18] Amer. Chem. Journal **26**: 539–566. 1901.

[19] WEEVERS, TH., and MRS. C. J. — DE GRAFF, Investigations of some xanthine derivatives in connection with the internal mutation [metabolism] of plants. Proc. Koninkl. Akad. Wetens. Amsterdam **1903**: 203–208 (meeting of Sept. 26).

VOSS FINDS that fusion and clamp-connections between hyphae, so well known in basidiomycetes and the higher ascomycetes, occur also in the Uredinales.[20] Sometimes the fusing hyphae are closed at the point of connection by a partition wall, sometimes there is an open fusion or plasma threads pass through the wall. From these structures he argues the correctness of Meyer's view that the Uredinales became early in development a distinct offshoot from the fungus stem.—C. R. B.

MOLISCH HAS HAD exceptional opportunities for studying the excretion of water from the leaves of a caladium (*Colocasia nymphaefolia* Kth).[21] He finds that drops are ejected under favorable conditions with some force (rising 1 cm), and so rapidly (up to 190 per minute) as to give the impression of a minute stream from a fountain, as Muntingh describes it in 1672, a statement which Pfeffer declares an exaggeration.[22] In a single night 97 cc were given off and in a week 1008 cc. Molisch's figures all far exceed those quoted by Pfeffer.—C. R. B.

IN THEIR STUDIES of the Scottish fresh-water plankton, W. and G. S. West,[23] have reached the conclusions that Scottish phytoplankton differs considerably from that of the western parts of continental Europe; that it is unique in the abundance of its desmids, the most conspicuous of which are of type confined almost exclusively to the extreme western and northwestern shore districts of Europe and to North America; that there is a remarkable scarcity of many of the free-swimming Protococcoideae; and that the plankton is much richer in species in the late summer and autumn than in the spring.—J. M. C.

IN A BRIEF NOTE, with five text figures, Emma Lampa describes[24] an exogenous occurrence of Anthoceros antheridia. Spores were sowed so thickly that the resulting plants grew upright or overrode one another. Upon some of these somewhat etiolated specimens antheridia developed from epidermal cells, along with others that arose in the normal fashion from underlying tissue. Aside from the method of origin and the fact that the exogenous antheridia ranged free above the dorsal surface of the thallus, they did not differ in appearance or mode of growth from the endogenous type. The author regards the exogenous antheridia as a reversion to the ancestral type, thus explaining the persistent wall of the sunken antheridium as vestigial.—FLORENCE M. LYON.

[20] VOSS, W., Ueber Schnallen und Fusionen bei den Uredineen. Ber. Deutsch. Bot. Gesells. **21**: 366–371. *pl. 19.* 1903.

[21] MOLISCH, H., Das Hervorspringen von Wassertropfen aus der Blattspitze von *Colocasia nymphaefolia* Kth. Ber. Deutsch. Bot. Gesells. **21**: 381–389. *pl. 20.* 1903.

[22] PFEFFER, W., Pflanzenphysiologie **1**: 262. 1897.

[23] WEST, W. and G. S., Scottish fresh-water plankton. No. 1. Jour. Linn. Soc **35**: 519–556. *pls 14–18.* 1903.

[24] LAMPA, EMMA, Exogene Entstehung der Antheridien von Anthoceros. Öster. Bot. Zeits. **53**: 436–438. *figs. 5.* 1903.

NEWS.

PROFESSOR E. L. GREENE has begun a new publication bearing the title "Leaflets of botanical observation and criticism," in the style of *Pittonia*. The first fascicle (16 pp.) of the first volume was issued November 24, 1903, and the second January 5, 1904.

OTTO G. JENNINGS, formerly herbarium assistant in the botanical department of the Ohio State University, has been appointed custodian of botanical collections at the Carnegie Museum, Pittsburg, Pa., *vice* John Shafer, who goes to the New York Botanical Garden.

IN HIS SOUTHPORT address as president of the botanical section of the British Association, Mr. A. C. Seward spoke of the "Floras of the past; their composition and distribution." The address is an admirable presentation of our knowledge and lack of knowledge of the paleobotanical record.

AT THE St. Louis meeting of the American Association for the Advancement of Science Professor W. G. Farlow was elected president of the Association, and Professor B. L. Robinson vice-president of the Section of Botany. The Botanical Society of America elected Dr. Frederick V. Coville president.

THE *Forestry Quarterly* will contain hereafter both original papers and reviews of literature. It is to be hoped that complete and accurate citations will be given of articles so reviewed. This is not done in the first number. We commend to the *Quarterly* the style adopted ten years ago by the botanists and now widely used both here and abroad.

E. W. D. HOLWAY, of Decorah, Iowa, has presented to the botanical department of the University of Minnesota his library and collection of fungi. The library contains about 1000 volumes, and the herbarium, including duplicates, is estimated to contain from 85,000 to 100,000 specimens. Mr. Holway plans to devote himself hereafter to the study of fungi and will probably reside in Minneapolis when not in the field.

A NEW PERIODICAL has made its appearance as the organ of an "Association of Representatives of Applied Botany," which is devoted to the advancement and deepening of scientific knowledge in the service of agriculture, forestry, trade, and industry by botanical investigation. The Association begins auspiciously, with a membership of over 100. Any botanist is eligible who is active or interested in the objects of the society. The first volume (1903) of the *Jahresbericht der Vereinigung der Vertreter der angewandten Botanik* can be obtained from Gebrüder Borntträger for *M* 4.

A BARE STATEMENT of the facts leading to the closing of the New York State College of Forestry is given by the editor in the *Forestry Quarterly* **2**:42. November 1903. This statement throws little direct light upon the matter, though one may read between the lines. Apparently the governor's veto of the appropriation for the College was secured by the "pull" of certain owners of Adirondack lands whose estates adjoined the reserve, because they were not pleased with the logging and other operations inaugurated by the College. This is practically acknowledged by Governor Odell in his recent message to the legislature. From this message it is apparent that the veto was not based upon condemnation of the practice of the College by expert foresters, but upon the "disapproval" of its work by "many citizens of the state." The plea he makes is that the object of the state was to conserve the water supply by retaining the forest cover, while the College was completely denuding its experimental forest! Surely the people of New York will not accept such a worthless defense.

THE CATALOGUE DIVISION of the Library of Congress has sent to press, and will issue shortly, through the office of card distribution, a set of analytics for Engler-Prantl's *Die natürlichen Pflanzenfamilien*. Each article (family) in this important set of monographs will be represented by a separate catalogue card, which contains full bibliographical information, including exact dates of publication for undated signatures. Beside subject headings, all added entries will be printed in full.

The cards covering the unfinished portions of the work will be issued upon the completion of the volumes in question. The number of titles now going to press is 458, and the total number of cards necessary for main entries, subjects, and added entries will be 936. These may be obtained at the office of card distribution.

The task of analyzing this and other collective works of similar importance, titles of which will be announced later, has been performed by Mr. J. Christian Bay. Owing to the exacting demands of necessary work in other directions, the Library has so far undertaken but little work of this character.